

Solar Energy

asep



AUSTRALIAN SCIENCE EDUCATION PROJECT



Man has to provide power to light up cities when the Sun is not shining.

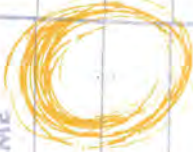
This book is part of the learning material developed by the Australian Science Education Project (ASEP). The Project was funded by the Commonwealth and State Governments of Australia.

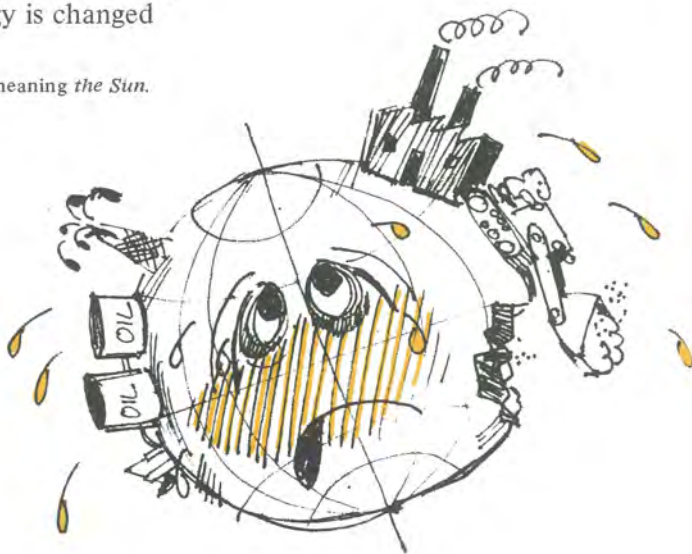
When primitive people discovered fire, they had found a means of releasing the energy stored in wood. Mankind then learned how to use the energy of wind and running water. In time, people found they could release energy from coal and oil, too. Today, mankind's energy requirements are rapidly depleting the energy stores.

Since the Earth's stores of energy are limited, people have to investigate all possible sources of energy.

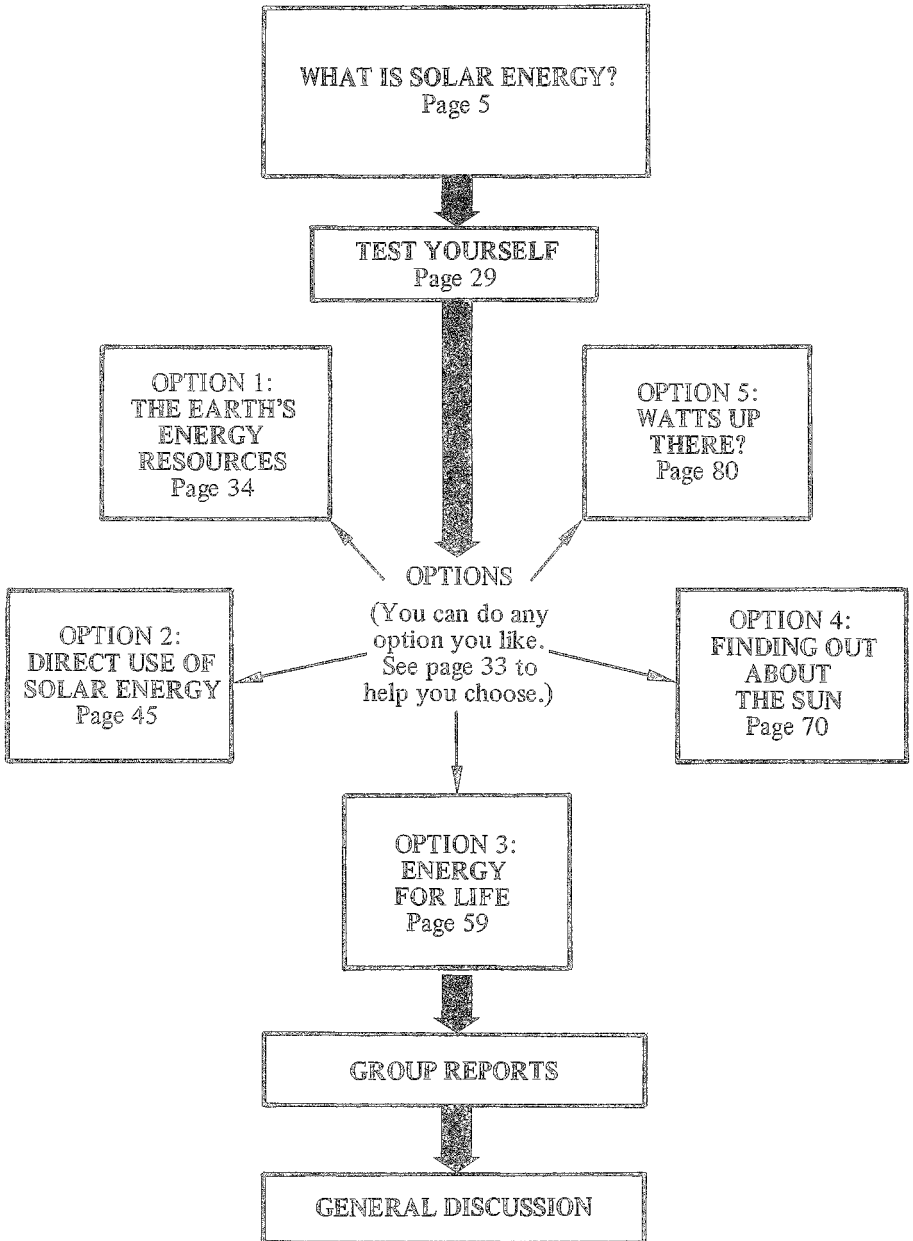
Solar Energy* describes why energy from the Sun (solar energy) is essential to life on Earth as we know it. You will find out some of the many ways in which this energy is changed and stored.

* From the Latin word *solaris*, meaning *the Sun*.

BUSBY HIGH SCHOOL	CLASS	
	NAME	
DATE		



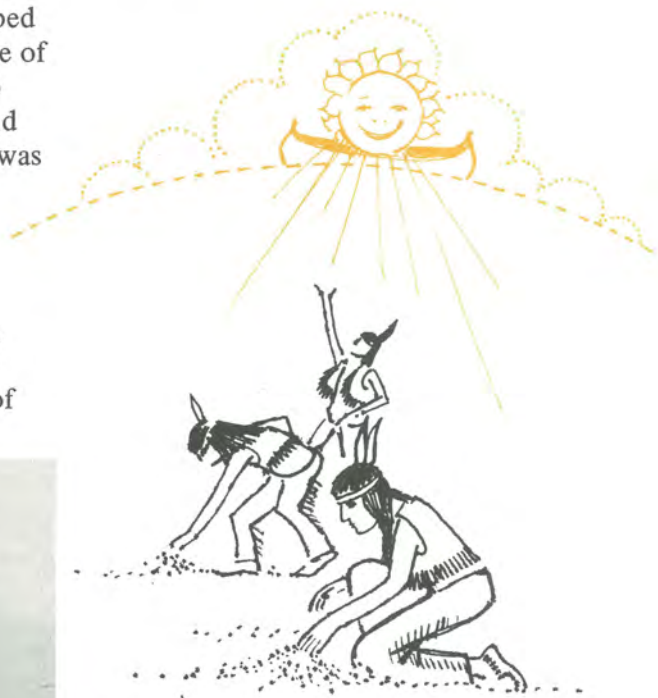
PLAN



What Is Solar Energy?

Many ancient peoples worshipped the Sun. This was particularly true of agricultural peoples, who came to associate the Sun with warmth and the growing season. Solar energy was needed for the growth of crops. From these crops the people obtained some of their own energy requirements.

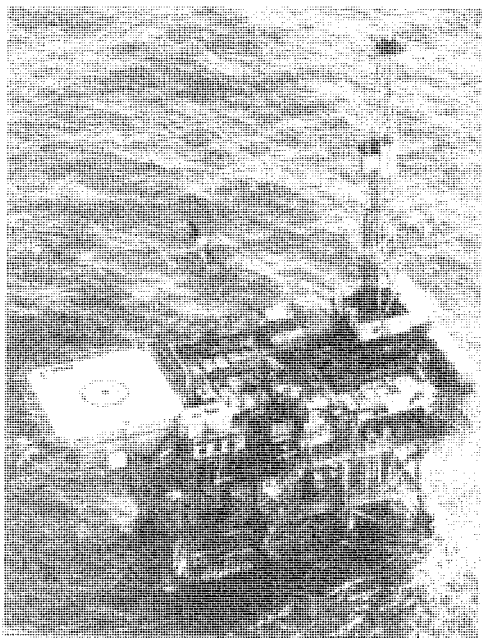
In Ancient Egypt, for example, the Sun god, Re, was regarded by the people as the most powerful of the gods.



Some people believed that the Sun travelled across the sky in a canoe and told them when to plant seeds.

The Sun god, Re.

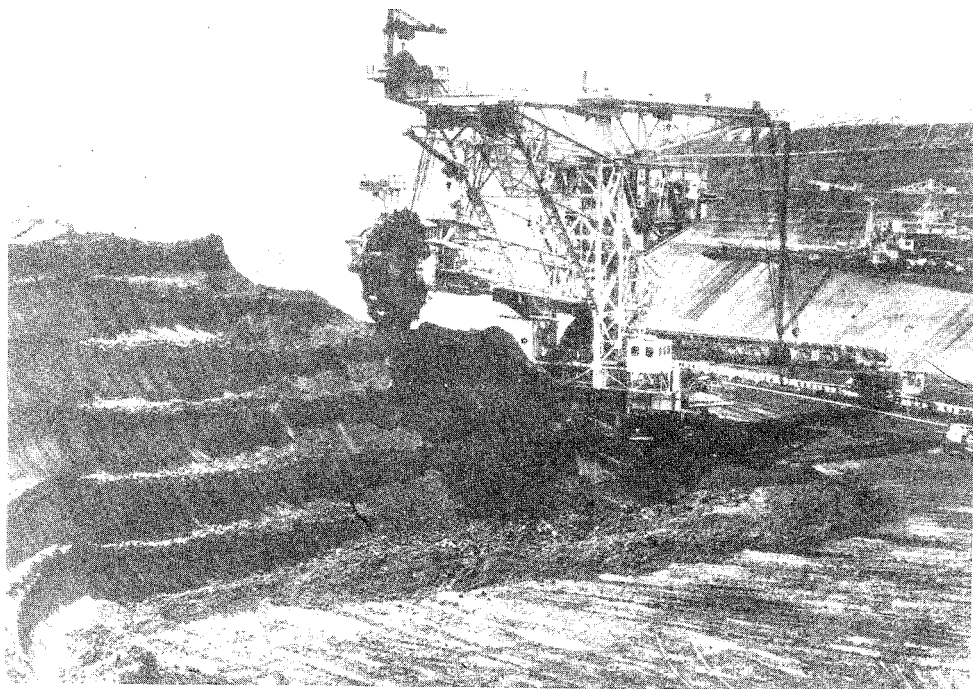
(Photo by courtesy of the Australian Institute of Archaeology.)



(Photo by courtesy of Petroleum Information Bureau (Aust.).)

*At left. An oil rig.
Below. Open-cut mining. Brown coal
dredger, Morwell, Victoria.*

Today, people require energy to heat and light homes and to run machines. People depend on a number of sources of energy. Some of these sources are shown in the photos on these pages. The energy stored in the petroleum, in the coal and in the lake behind the dam can be transformed (changed) into other forms of energy useful to mankind. Heat, light, electricity and kinetic energy (the energy of moving objects) are some of the forms that can be produced from these sources.



(Photo by courtesy of State Electricity Commission of Victoria.)



The energy in water moving from a dam can be transformed to electric energy.

(Photo by courtesy of State Rivers and Water Supply Commission of Victoria.)

Yet when you consider the energy stores shown in the photos, you realize that each obtained its energy indirectly from the Sun.

Take petroleum, for example. It is now believed to have been formed millions of years ago from tiny animals and plants. The animals' food was plants. In turn, the plants required energy from the Sun for growth. The solar energy used during the plants' growth is now stored in the petroleum.



1 Discuss with other students why the water in the dam and the coal are, indirectly, stores of solar energy.



Whenever you see the sign  followed by a number it means that there is something to do in your record book.



Underground steam escaping in the thermal region of New Zealand.

(Photo by courtesy of New Zealand Government Tourist Bureau.)

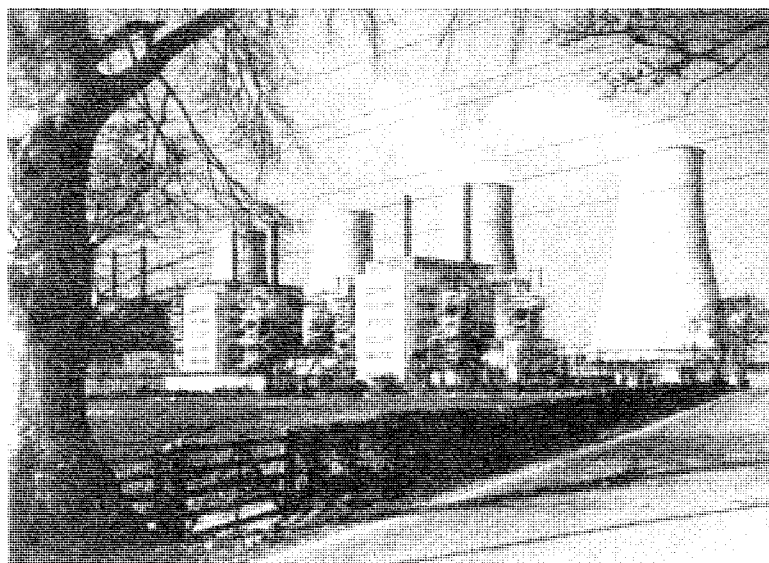


2 In the search for other sources of energy, mankind has discovered some which do not depend on solar energy. Examples are shown in these photos. Try to suggest where the various types of energy come from. You could discuss this question with other students.

Usually it is necessary to transform energy from one form to another to use it. For example, to transform the stored (chemical) energy in petrol into kinetic energy (the energy of moving objects) you can use a petrol engine. The engine produces heat and sound at the same time.



3 What energy transformations occur in a transistor radio?



A nuclear power station.

(Photo by courtesy of United Kingdom Atomic Energy Commission.)

Human beings need energy for their bodies as well as for their machines. Green plants transform solar energy in the process of **photosynthesis** (making their own food) and we eat either plant products or animals (who, in turn, have fed on plants).



Some Facts about Solar Energy

Solar energy is radiated through the 150 million kilometres of space which separate the Sun and the Earth. Not all of this energy can penetrate the atmosphere and reach the Earth's surface. Two of the forms which can do so are heat and light.

When sun-bathing you will have noticed that a cloud across the Sun immediately reduces both light energy and heat energy. This suggests that the light energy and heat energy in the radiation must be travelling at exactly the same speed from the Sun to the Earth.

In the activities which follow you can find out more about the energy the Sun radiates.



ACTIVITY 1: LOOKING AT SOLAR ENERGY AT WORK



A radiometer.

In this activity you will use an instrument called a **radiometer** to find out more about energy transformations. It will be similar to that shown in the photo at left.



4 Observe what happens when the radiometer is placed first in the dark and then in direct sunlight (or near a powerful light globe). Take it near a room heater (or any other heat source). Record your observations.



5 The radiometer transformed energy from one form to another. How would you describe the energy transformation which occurred? Suggest explanations and, if possible, test them.

You may want to discuss your suggestions and tests with other students and/or a teacher.

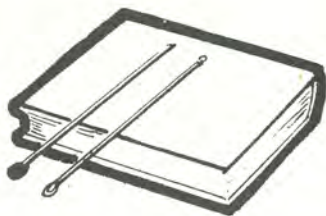
Perhaps the following investigation may cause you to change your mind. You use two surfaces similar to the shiny and black surfaces on the radiometer.

You will need:

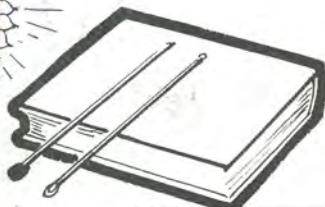
- a position in direct sunlight (or near a 100 W globe)
- 2 thermometers, -10°C to 110°C . One will need to have a blackened bulb.



6 Place the thermometers in shade. Record the reading of each thermometer. Wait for several minutes and repeat the readings.



7 Now place the two thermometers in direct sunlight (or about 15 centimetres from the 100-watt globe). After several minutes again note the thermometer readings.

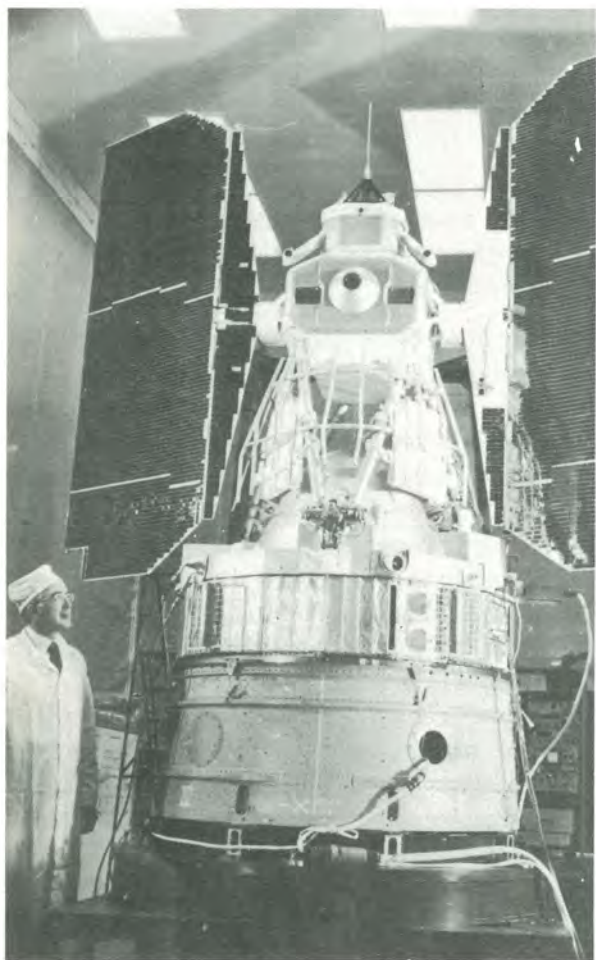




8 What effect does the black coating have on the thermometer readings? Explain your observations.

Do your observations support your suggestions for the behaviour of the radiometer? You may wish to change your conclusions in  5.

MORE SOLAR ENERGY AT WORK



The satellite shown here can be powered by solar cells. Solar radiation is transformed into electrical energy by these cells.

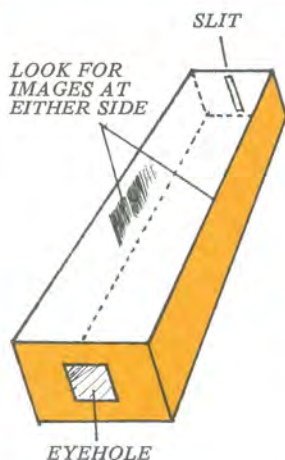
You may be able to see a solar cell working.

The radiometer and the solar cell are just two examples of solar energy at work.

One of the colour photos in the centre of this book has been taken by this satellite.

(Photo by courtesy of NASA.)

ACTIVITY 2: VISIBLE AND INVISIBLE RADIATION



Never point a spectroscope directly at the Sun. Direct sunlight can harm your eyes.



In 1664, Sir Isaac Newton (1642–1727), British natural philosopher, made a discovery about the composition of sunlight. In this activity you have a chance to find out what he discovered and how he made his discovery.

THE VISIBLE

There are a number of ways of showing Newton's discovery. For the method given here you will need an instrument called a **direct vision spectroscope**. (A teacher may show you other methods.)

Keeping the slit vertical, point the spectroscope to the sky.



9 Look through the eyehole. Describe what you see at the sides of the spectroscope. You may like to draw what you see.

Did other students get the same effect? Were the colours they observed the same as the ones you saw?

This band of different colours—which is what Sir Isaac Newton discovered—is called the **spectrum of white light**. White light is a combination of various colours. A spectroscope separates the colours. Sunlight is often called **white light**.

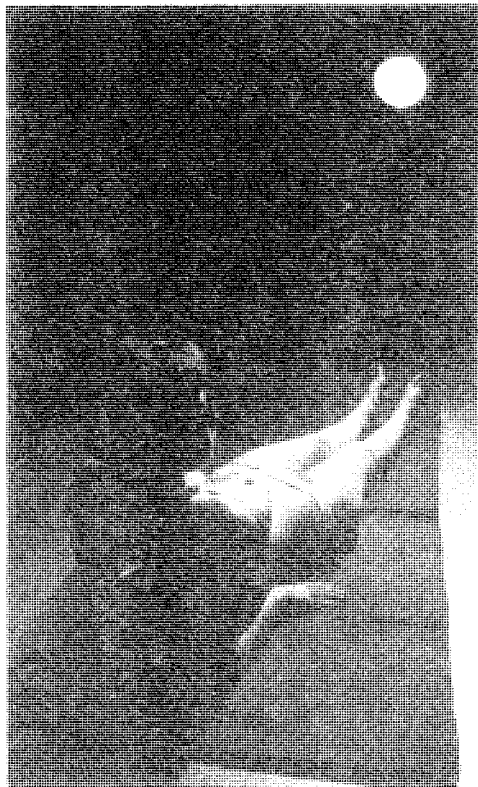
Look at the colour photo of the spectrum of white light in the centre of this book. The spectrum you saw probably did not look as clear as this. However, you probably saw six different basic colours—red, orange, yellow, green, blue and violet. Sometimes indigo is included as a separate colour between blue and violet. But not everybody sees indigo as a different colour.

Newton did not have a spectroscope like the one you have been using. His investigation was done in a darkened room. He allowed a narrow beam of sunlight from a hole in a curtain to pass through a glass prism. You could try to repeat Newton's work.

THE INVISIBLE

In the parts of the spectrum just beyond the blue and red zones, there are types of radiation to which your eyes are not sensitive. These include:

- the ultra-violet radiation, which extends beyond the blue/violet zone, and
- the infra-red radiation, which extends beyond the red zone.



*Ultra-violet aid to beauty:
getting an artificial suntan.
Note the protective covering
over the girl's eyes—ultra-
violet light damages the eyes.*

Ultra-violet Radiation

It is the ultra-violet radiation in sunlight that causes sunburn. It also produces vitamin D in your skin.

Special lamps can produce a high proportion of ultra-violet radiation. These lamps may be used for health and beauty reasons.

Geologists also use such lamps to help them identify minerals because some rocks glow (fluoresce) when they absorb ultra-violet light.



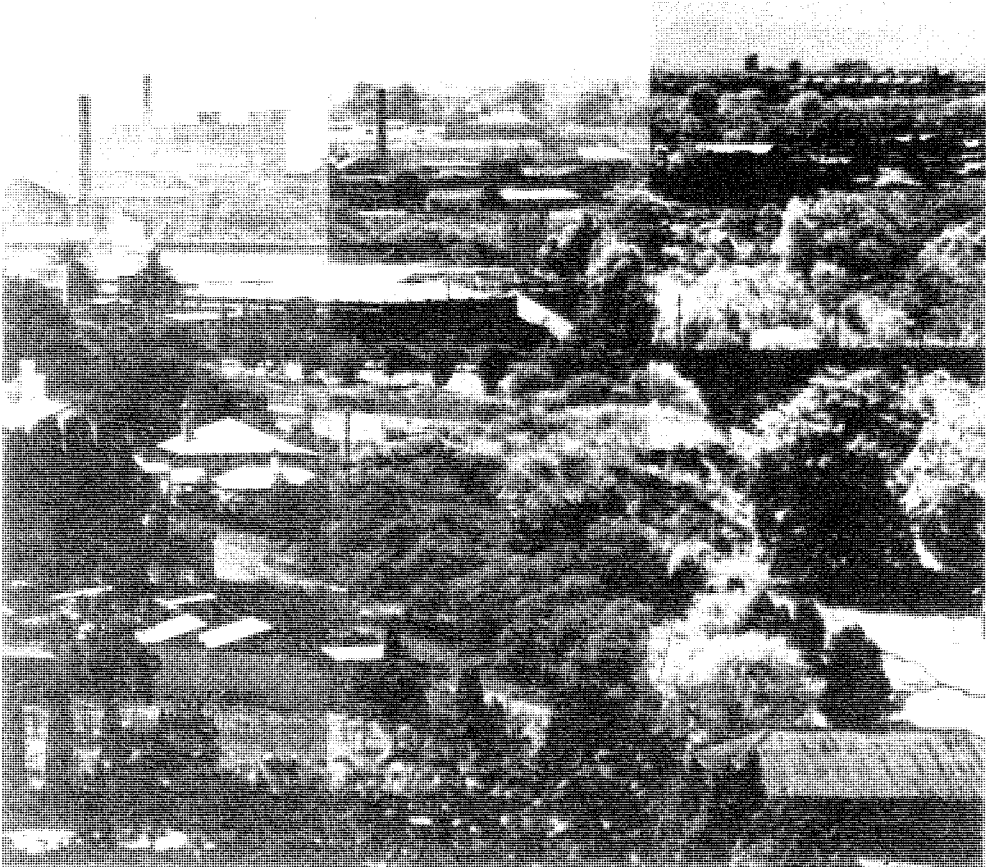
Minerals photographed in ultra-violet light.

Infra-red Radiation

When radiation is absorbed by an object, the object gets warmer. This is why you feel warm in sunlight. A spectrum can be projected on to a screen. Sensitive instruments placed in the spectrum beyond the red zone will detect the temperature rise resulting from the absorption of infra-red radiation.

All objects emit infra-red radiation to some extent. Some photographic films are sensitive to infra-red.* You can also take photos using ultra-violet light only. Such films will detect radiation which the eye does not see. The scene below was photographed with normal, infra-red and ultra-violet sensitive films.

* This means that emulsion in the film will start to change when infra-red radiations fall upon it. Ordinary film does not do this.



White light.

Infra-red sensitive.

Ultra-violet sensitive.

Other Radiation



Solar radiation includes other forms of radiation invisible to the human eye. Instruments are used to detect these. All these radiations together make up the total spectrum.

ENERGY AND COLOUR

You have seen several kinds of solar radiation and their different effects. The stream of energy coming from the Sun contains far more than you have encountered. Are there many differences between the different forms of solar radiation?

For some purposes it is convenient to think of radiation as arriving in small pulses (bursts) of energy.

All radiation pulses travel at the same speed—the speed of light (3×10^8 metres per second in a vacuum). However, the pulses can have different amounts of energy.

Most people see a certain colour when a certain energy falls upon the sensitive surface of the eye. For instance, most people see red for one particular energy; yellow for another; and so on. (Colour-blind people cannot distinguish between certain colours, for instance red and green.)

Every part of the spectrum corresponds to a definite energy value.

It is the difference in energy that accounts for the different effects that can be observed. Radio pulses, for example, contain less energy than infra-red radiation pulses. Infra-red pulses have less energy than pulses of ultra-violet radiation.

DETECTORS

Different kinds of detectors are needed to show the presence of the different forms of solar radiation. For example:

- Your eye detects visible radiation (light). You may like to find out how the eye functions, and why it is sensitive only to visible radiation.
- A blackened thermometer bulb detects infra-red radiation.
- A radio receiver detects radio pulses. Radio pulses from space can be received by radio telescopes such as the one shown below.

Elsewhere you may see the spectrum described in terms of 'wavelengths' or 'frequencies'. These terms are based on the theory that radiation has wave-like features. So don't get confused when you see something like radio pulses referred to as radio waves.

In the diagram on page 15, notice the limited range occupied by the visible spectrum in the total spectrum. It is mainly the visible region that you will be studying in *Solar Energy*.



*A radio telescope—Parkes, NSW.
(Photo by courtesy of CSIRO.)*

ACTIVITY 3: WHAT HAPPENS TO SOLAR ENERGY?

What happens to the radiation from the Sun as it approaches the Earth? Depending on the kind of object it strikes, solar energy may be:

- ☐ reflected (bounced off)
- ☐ transmitted (passed through)
- ☐ absorbed.

You can see this for yourself in this activity.



All around you there is colour. You have seen that sunlight is a mixture of different values of energy corresponding to different colours. Have you considered why objects appear to be a particular colour?

To help you answer this question, you can find out the effect that various materials have on the spectrum of white light.

You will need:

- 1 spectroscope
- 1 set of coloured filters (transparent material)
- pieces of coloured materials such as wool or other fabrics (opaque* materials)
- at least 1 green leaf
- 1 sheet of shiny white paper
- 1 sheet of matt (non-shiny) black paper.

* opaque means will not allow light to pass through.



10 Place various coloured filters over the slit of the spectroscope and look at indirect sunlight. Make notes about your observations.



11 Look through the spectroscope at light reflected by shiny white and matt (non-shiny) black paper.



12 Look through the spectroscope at light reflected from various coloured materials, and green leaves. (Try pointing the spectroscope toward the sky, then moving it to green trees and other coloured objects.)



13 You should now be able to answer the four questions on page 7 of your record book. Discuss the answers with others if you are in any doubt.

IN THE EARTH'S ATMOSPHERE

You have seen that radiation striking an object may be partly reflected, partly transmitted or partly absorbed.

When solar radiation enters the Earth's atmosphere similar effects occur.

Reflection

Reflection of energy occurs at cloud surfaces, from airborne dust particles and at the Earth's surface.

Reflection from dust particles and clouds prevents some energy from reaching the Earth's surface.

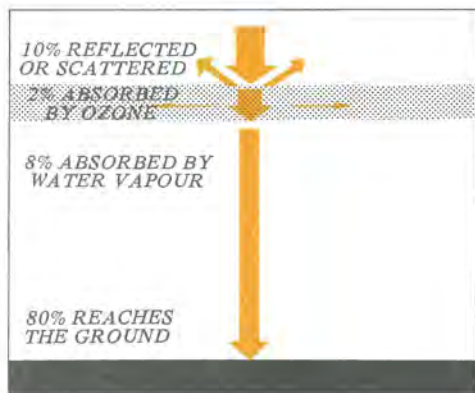
Absorption

Absorption of energy occurs at the Earth's surface and also in the atmosphere. Much non-visible radiation is absorbed by the colourless gases in the atmosphere such as ozone, carbon dioxide and water vapour.

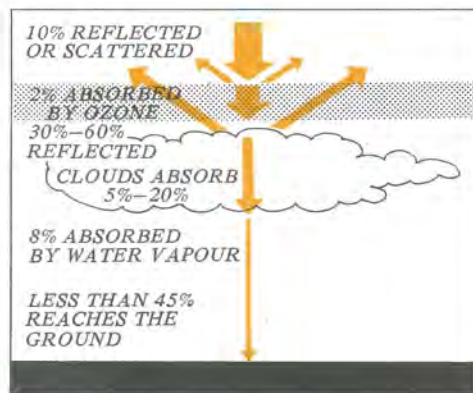
Ozone gas in the upper atmosphere, for example, absorbs much of the **ultra-violet radiation**. Life on Earth has slowly evolved (changed with time) to withstand present levels of ultra-violet radiation. However, any marked increase in this radiation could have far-reaching effects. There are people who are very concerned about the effect of high-flying jet planes on the protective ozone layer. (See *Frontiers of Science* reprint on page 20.)

Some **infra-red radiation** is absorbed by water vapour, carbon dioxide and clouds.

The diagrams below show the approximate percentage of incoming radiation lost on a clear day and a cloudy day by reflection, absorption and what is called **scattering**.



Clear sky.



Cloudy sky.



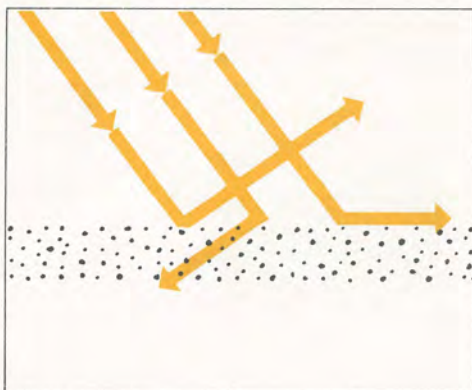
*Part of the Earth, covered by cloud, as seen from space.
(Photo by courtesy of NASA.)*

On a clear day, of the total radiant energy reaching the Earth's surface about 10 per cent is ultra-violet, 45 per cent is visible and 45 per cent is infra-red.



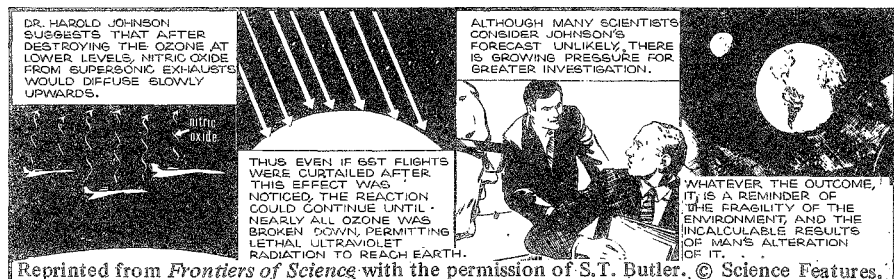
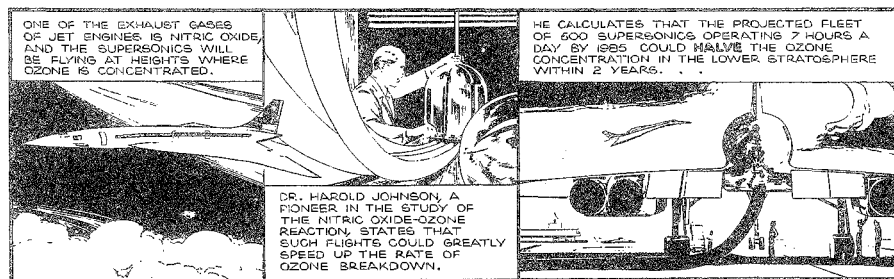
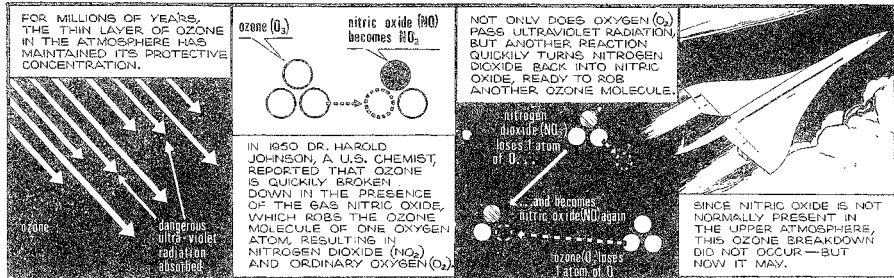
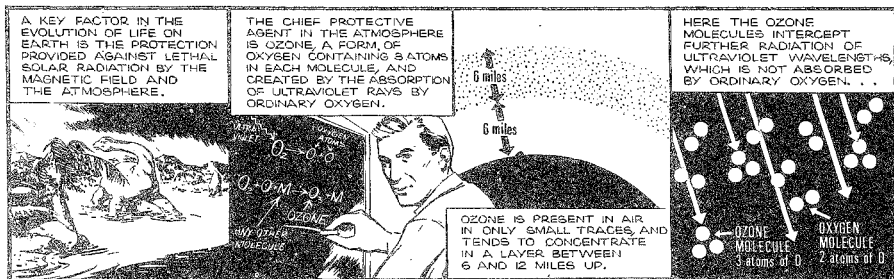
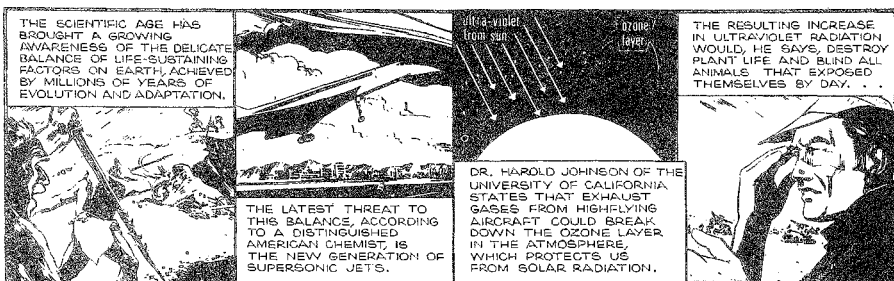
Reflection

Light meets a surface and is bounced back in a given direction.

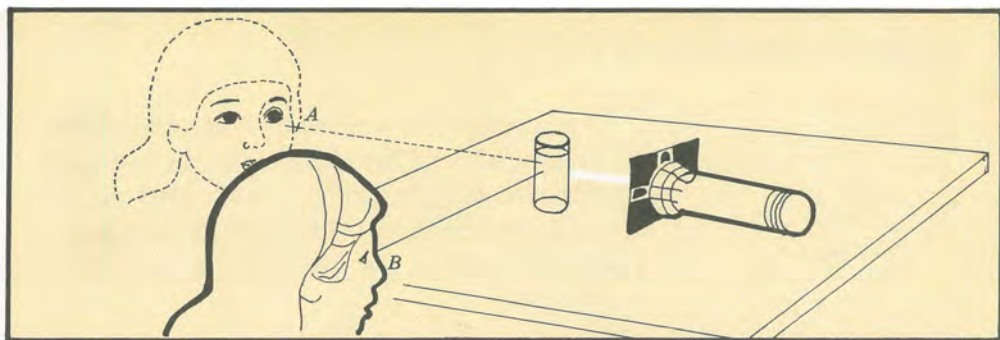


Scattering

Light pulses are absorbed by some fine particles in the atmosphere, then re-emitted in every direction. This happens more for higher energy pulses; for example, the blue-violet sections of the visible spectrum.



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ACTIVITY 4: BLUE SKIES AND RED SUNSETS

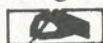
You can now find out more about the scattering of light in the Earth's atmosphere.

A darkened corner of the room is best for this activity.

You will need:

- 1 vial
- 1 dropper
- 1 ml of milk
- access to a narrow beam of light—a torch with a cardboard mask is suitable.

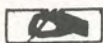
Add about eight drops of milk to the vial. Fill the vial with water and shake it. Shine the beam of light into the vial as shown in the diagram above.



14 What colours do you see when looking at the beam from A? From B?

The suspended particles of milk act in much the same way as particles of dust and water vapour act in the atmosphere.

In the vial, you saw white light being scattered. The red light pulses were scattered less than the higher energy blue light pulses.



15 Using the idea of scattering of light, try to answer the two questions below.

- Why does the sky at the horizon often appear red at sunset? (Hint: Consider the path of sunlight through the atmosphere at midday and at sunset.)
- Why are some cars fitted with orange-yellow fog lights?

Notes:

1 6 miles = 10 km

2 Wavelength is another way of presenting the various energy ranges

3 SST = Super Sonic Transport

AT THE EARTH'S SURFACE

You have seen how suspended particles affect the transmission of light. Similarly, the radiation reaching the Earth's surface is controlled by atmospheric conditions. That radiation which reaches the surface may also be reflected or absorbed.

Reflection

What kinds of surfaces would you expect to reflect most radiant energy?

The amount of light energy reflected from various surfaces can be measured using a light-meter. This is an instrument which transforms light energy into electrical energy. A needle moving across a scale indicates the amount of light entering the meter from various sources.

If a light-meter is available, you could use it to compare various surfaces.

The meter is a delicate instrument. If you are using sunlight, do not point it directly at the Sun. Instead, point it at the surface you are testing.



A photographer's light-meter.



16 On page 9 of your record book enter your results. You could make a table for the light-meter readings and compare them with the readings for a white surface.

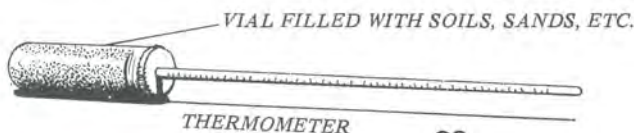
Absorption

Some absorbed radiation will cause heating of the Earth's surface. To see which substances absorb most, you could expose soils, sands, gravels, etc., of different colours and grain sizes to solar radiation (or radiation from a light globe).

You could use the idea suggested in the diagram at left.



17 Record your observations on page 9 of your record book.



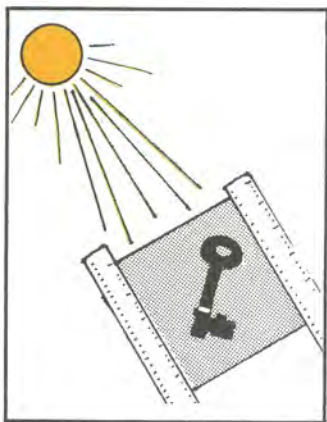
ACTIVITY 5: LIGHT ENERGY AND CHEMICAL CHANGE

Not all absorbed radiation is used to raise the temperature of substances.

Substances, whether simple or complex, are built up from atoms. The atoms are linked to each other by chemical bonds. During a chemical change bonds are broken and different atoms may become linked together forming new substances. Sometimes absorbed radiation, for example a pulse with a particular energy, is sufficient to break a bond and so enable new links to form.

Chemical reactions are involved in making blueprints. To see this happening you will need:

- some sheets of blueprint paper
- access to a light-tight box (or a darkroom).



A blueprint can be made by placing an opaque object (for example a key) on the surface of the blueprint paper and exposing it to sunlight (or artificial light) for a short time. Do not move the object during this time.

(The exposure time necessary depends on the type of blueprint paper. You may need to try several different exposures to obtain a good blueprint.)

Afterwards, wash the paper thoroughly in cold running water. Leave the paper to dry.



18 Describe what happened.

Chemical reactions which are much more important to us than blueprints or photographs occur in green plants. These changes are brought about by light energy. You can find out more about these changes in the next activity.

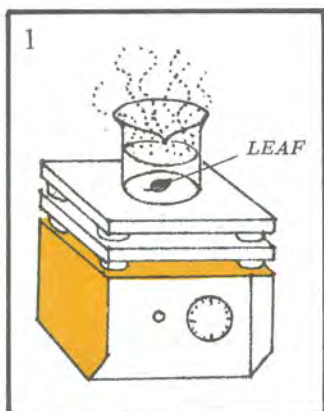
ACTIVITY 6: NATURE'S ENERGY TRAP

In Activity 3 you found that coloured filters absorb certain parts of the visible section of the solar spectrum, but transmit others. You also probably found that green plants absorbed some of the visible light striking them and reflected some as well.

In this activity you can find out more about the particular energy absorbed by green plants. You can start your investigations by making a solution of chlorophyll (the green colouring matter in leaves).

You will need:

- 1 small, soft green leaf—avoid hard, brittle leaves
- 1 small beaker
- 2 vials
- 1 heater
- 1 spectroscope
- methylated spirit (alcohol).



Caution: Alcohol is flammable. If you use a gas flame for heating, the boiling alcohol may catch alight. To put it out, simply block the mouth of the vial with the second vial.

- 1 Add the leaf to 30 millilitres of boiling water for about 30 seconds.
- 2 Transfer the leaf to one of the vials and cover it with the alcohol.
- 3 Heat the alcohol by placing the vial in the beaker of gently boiling water.

Colouring from the leaf dissolves in the alcohol, turning it green.

Pour the green solution into the other vial.

Use the spectroscope to view the spectrum after white light has passed through the green solution.



Remember: Don't look directly at the Sun.



19 Describe the appearance of the spectrum.

The spectrum left after certain energies of light are absorbed is called an **absorption spectrum**.

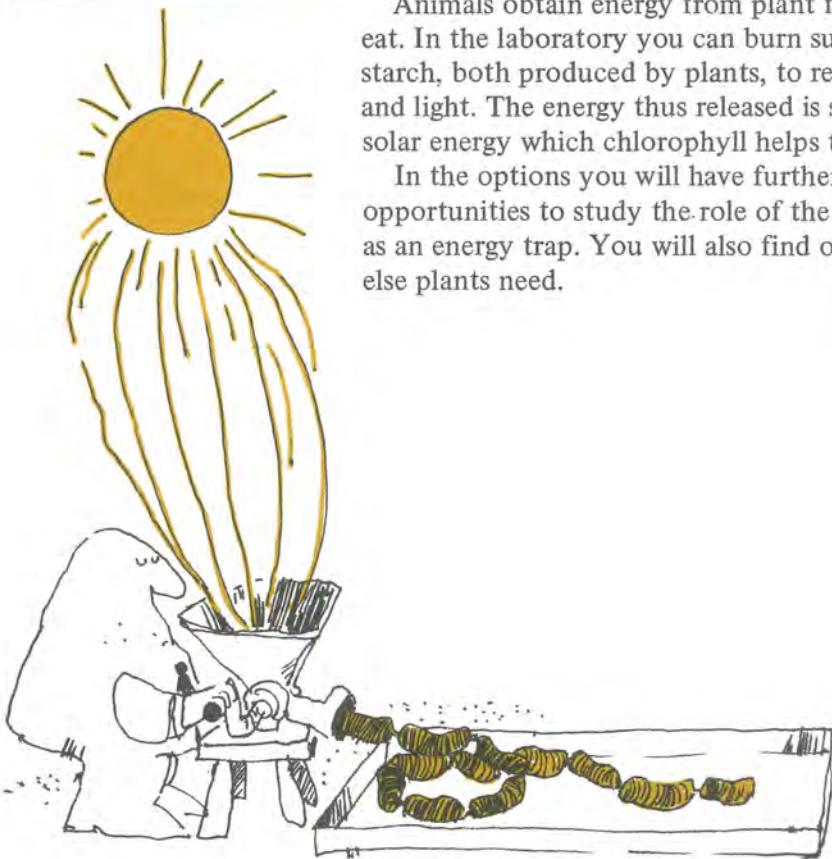
The absorption spectrum from the chlorophyll solution was probably similar to the spectrum you saw for white light reflected from a green leaf in Activity 3.

Many tests like the one you have just done have established that the chlorophyll in plants is responsible for absorbing certain colours (energy range) of the visible section of the solar spectrum.

A reproduction of the absorption spectrum for chlorophyll is shown in one of the colour photos in the centre of this book.

Animals obtain energy from plant foods they eat. In the laboratory you can burn sugar and starch, both produced by plants, to release heat and light. The energy thus released is some of the solar energy which chlorophyll helps to absorb.

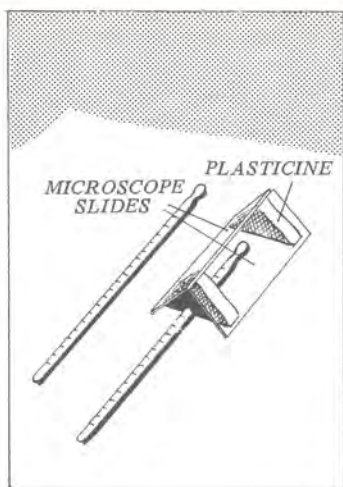
In the options you will have further opportunities to study the role of the green plant as an energy trap. You will also find out what else plants need.



ACTIVITY 7: THE GLASSHOUSE EFFECT

You will need:

- 2 glass microscope slides
- plasticine
- 2 thermometers,
-10 °C to 110 °C
- 1 glass vial with a 1-holed
cap could replace the
microscope slides and plasticine.



In Activity 6 you saw how the green plant acts as an energy trap for solar radiation reaching the Earth. Nature traps energy in other ways.

To help you understand one way, set up the equipment as shown in the diagram at left, outside in sunlight. (What you are making is a model glasshouse.)



20 Record the temperature reading on each thermometer every minute for 10 minutes. When you have finished interpret the readings and make a short report about your findings.

To understand how a glasshouse works, you have to know that:

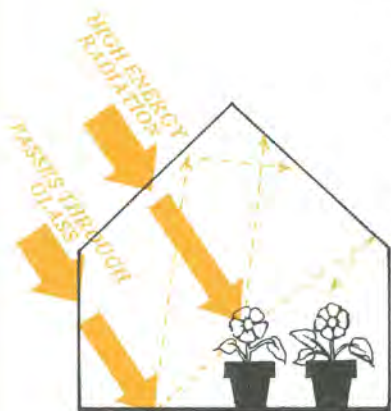
- glass and many other materials transmit high energy heat radiation, but not low energy heat radiation,
- the greater the temperature of an object, the higher the energy it radiates,
- the Sun's temperature is very much higher than that of objects on the Earth.

The atmosphere acts very much like a glasshouse.

Some high energy radiation from the Sun is able to pass through the atmosphere without being completely absorbed. This radiation heats the Earth's surface, which in turn radiates low energy infra-red radiation.

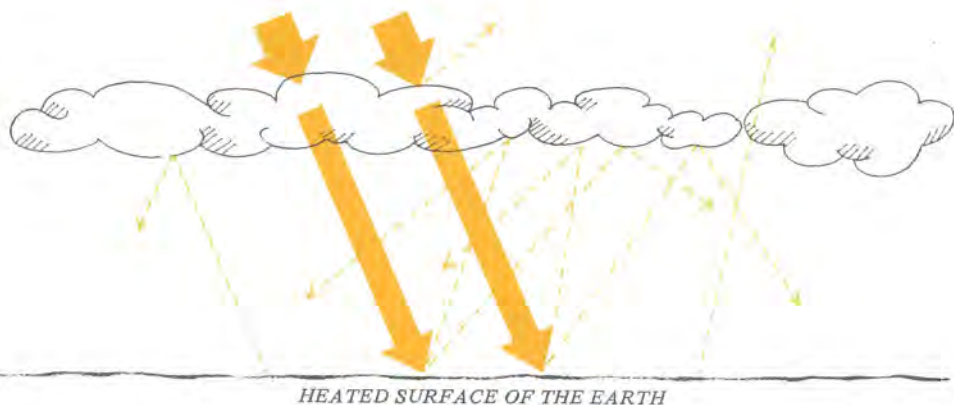
Part of this low energy radiation is absorbed by the lower atmosphere. The lower atmosphere radiates some energy back to the surface, and some into space.

This important effect, which to some extent controls the balance between incoming solar energy and outgoing radiated energy, is called the glasshouse effect. It is another one of nature's energy traps.



Plants, ground etc. absorb high energy radiation and re-radiate low energy radiation which cannot pass through glass.





HEATED SURFACE OF THE EARTH

It has been estimated that without this important effect, the average Earth temperature might be more than 30°C lower than it is!

The possible effects of pollutants, such as car exhaust gases, are worrying. There is a clash in the forecasts: some claim that the Earth will get hotter, others that it will cool.



21 Suppose there were an increase in the atmosphere of a particular gas known to transmit high energy radiation but to absorb low energy radiation. What effect might this have on conditions on the Earth's surface?

The passage of solar energy from the Sun to Earth is a hazardous one.

Reflection, absorption and re-radiation of energy occur in the atmosphere and at the land and water surfaces of the Earth.

Comparison of the polar and equatorial regions shows that not all areas receive the same amount of solar energy. However, air currents and ocean currents help to even out the effects of this uneven supply of solar energy.

Some energy is temporarily stored in green plants. This store becomes

the energy supply essential for the existence of living things. This energy is slowly released at a rate almost equal to its rate of storage. Animals feeding on plants absorb and partly release the energy—mainly as heat. The decay of plants and animals also releases heat.

However, a very small fraction of the vegetable and animal matter is buried and does not decay completely. This small fraction produced, in the past, the fossil fuels—coal and oil—that provide most of the energy for an industrial society.

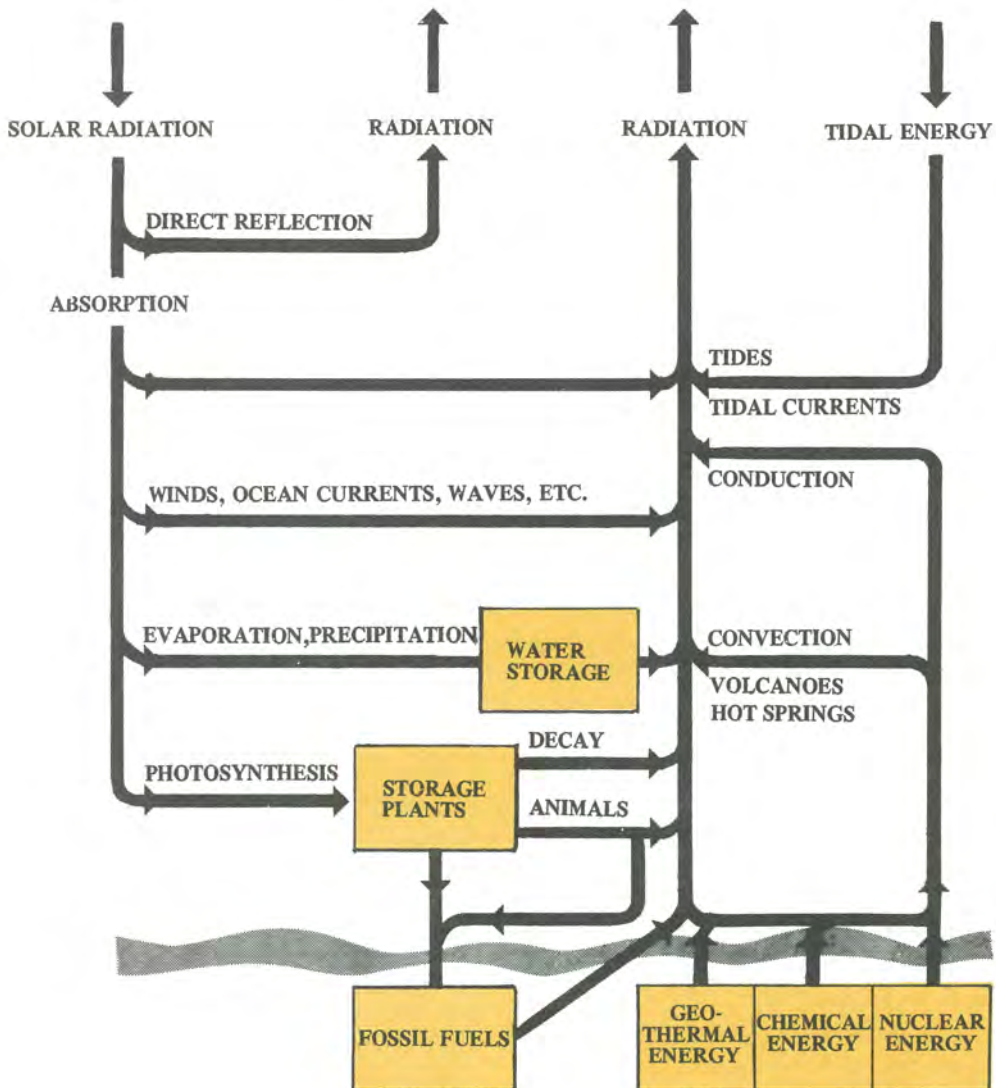
Why does mankind rely so much on this small fraction of solar energy trapped by plants? Can't people trap solar energy themselves and use it directly?

What problems are there in depending on fossil fuels as the Earth's main source of energy? What alternatives are there?

In the options you will have a chance to consider some of the above questions.

The chart on the next page will help to give you an overview of the flow of energy to and from the Earth.

ENERGY FLOW CHART FOR THE EARTH



You can check your answers by turning to page 89 of this book.

TEST YOURSELF—WHAT IS SOLAR ENERGY?

This test is to help you find out if you understand what you have been doing. It is not a test for marks.

Answer the following questions on page 12 of your record book. For most questions, you have to choose the best answer from the several answers suggested. In each of these cases, write only the letter of the answer which you choose.

It is important that all your answers are your own work.

- 1 Which one of the following best describes solar energy?
 - A Energy stored in fossil fuels
 - B Energy which comes from the Sun
 - C Chemical energy stored as food in plants
 - D Light energy

- 2 When using an electric hot-plate for cooking, most of the electrical energy is changed directly into
 - A heat.
 - B light.
 - C colour.
 - D chemical energy.
 - E kinetic energy.

Questions 3–9 refer to the key below. The key lists various kinds of radiation from the Sun.

Key	A White light	D X-rays
	B Infra-red radiation	E Radio waves
	C Ultra-violet radiation	F All of A, B, C, D and E

For each of questions 3–9 choose your answer from the key above. You may choose any letter more than once.

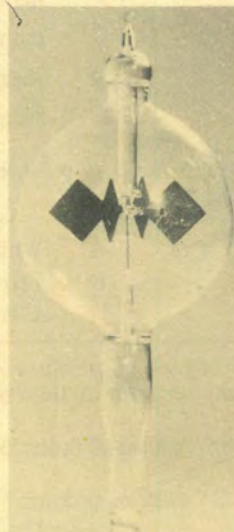
Which kind of radiation

- 3 causes sunburn?
- 4 may be broken up into a number of different colours?
- 5 is mainly responsible for warming the Earth?
- 6 can be seen?
- 7 can travel through space?
- 8 contains the part of solar energy which is 'trapped' during photosynthesis?
- 9 has pulses of lowest energy?

Test Yourself continued next page

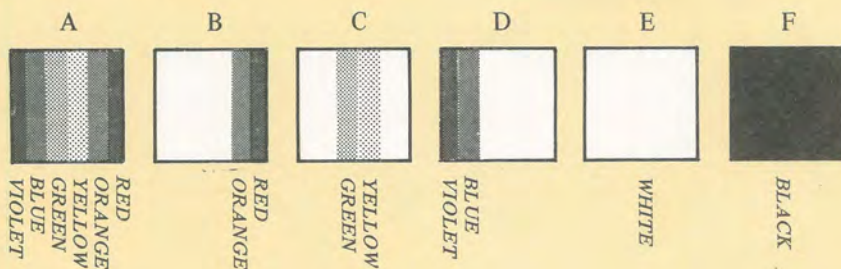
Test Yourself—What Is Solar Energy (continued)

- 10 Grass appears green because
- A grass absorbs green light.
 - B grass reflects green light.
 - C green light can pass through grass.
 - D green light remains on the surface of grass while other colours are reflected.
- 11 In its journey around the Earth, an artificial satellite is in sunshine for part of the time and shielded from the Sun by the Earth for the rest of the time. It is estimated that, while in the sunshine:
- ☐ if it were black, it would have a surface temperature of about 80°C .
 - ☐ if it were white, it would have a surface temperature of only about -60°C .
- Explain briefly why there would be this difference in temperature.
- 12 Most energy available on the Earth is obtained, directly or indirectly, from the Sun. Explain how hydro-electricity is obtained from the Sun.
- 13 The photo at right shows a radiometer. This radiometer is placed in sunlight. Which one of the following best summarizes the energy transformation taking place in the operation of the radiometer?
- ($\longrightarrow$ means 'is changed into')
- A Radiant energy $\longrightarrow$ kinetic energy
 - B Light $\longrightarrow$ heat
 - C Chemical energy $\longrightarrow$ kinetic energy
 - D Light $\longrightarrow$ chemical energy
 - E Kinetic energy $\longrightarrow$ chemical energy + heat
 - F Solar energy $\longrightarrow$ heat
- 14 White light, infra-red radiation, ultra-violet radiation and radio waves are all parts of the radiation from the Sun. Which one of the following describes one way in which they differ from each other?
- A They travel at different speeds.
 - B Each has a different colour from the others.
 - C The energy of the pulses in which they travel varies from one to the other.
 - D They travel along different paths from the Sun to the Earth.



- 15 Which one of the following best explains why, when the Sun is shining, the inside of a hothouse is warmer than the surroundings of the hothouse?
- A On passing through the glass (being transmitted), some of the visible light is changed to ultra-violet radiation which heats up the inside of the hothouse.
 - B Because the hothouse contains so much glass, more infra-red radiation reaches the inside of the hothouse than would reach the inside of other buildings.
 - C Because the glass is transparent it absorbs most of the radiation which strikes it. This causes the glass to become warm and thus to warm the inside of the hothouse.
 - D High energy radiation from the Sun is transmitted through the glass and is absorbed by the plants, etc., inside. These plants re-radiate low energy infra-red radiations which cannot pass out through the glass.
- 16 Sunlight is a combination of all the colours in the visible section of the solar spectrum. As sunlight comes through the atmosphere, the sky looks blue because
- A all the colours except blue are absorbed.
 - B blue light is scattered more than light of other colours.
 - C more blue colour is absorbed by the atmosphere than any other colour.
 - D there is more blue light than any other colour in sunlight.

Questions 17 and 18 refer to the diagrams below, which show what could be seen through a spectroscope in various conditions.



- 17 The spectroscope is pointed toward the sky. A vial of transparent red dye is placed in front of the spectroscope. Which one of the diagrams best shows what would probably be seen through the spectroscope?
- 18 The spectroscope is used to view sunlight reflected from a bluish piece of cardboard. Which one of the diagrams best shows what would probably be seen through the spectroscope?

Test Yourself continued next page

- 19 A spy wishes to photograph a building on the other side of a valley. The day is hazy. In order to get the clearest photo, which one of the following types of film should the spy use?
- A Infra-red sensitive
 - B White light sensitive
 - C Ultra-violet sensitive

Questions 20 and 21

An astronaut arrives on a new planet. He is surrounded by a gas which absorbs radiation of energy lower than that of green light. Radiations of energy greater than that of green light are transmitted.

- 20 In order to best photograph the surface of the planet, which one of the following types of film should the astronaut use?
- A Infra-red sensitive
 - B White light sensitive
 - C Ultra-violet sensitive
- 21 In order to best see where he is walking, which one of the following lamps should he use?
- A Infra-red
 - B Orange-yellow
 - C Blue-violet
 - D Ultra-violet

Now turn to Check Your Answers on page 91 of this book.

ABOUT THE OPTIONS

Here are summaries to help you decide which options to choose.

OPTION 1: THE EARTH'S ENERGY RESOURCES Page 34



Various stores of energy are available to mankind.

In this option you read about these resources and discuss the problems associated with them.

OPTION 2: DIRECT USE OF SOLAR ENERGY Page 45



Under certain circumstances and in certain areas direct solar energy could be a very desirable energy supply. How to tap this supply, and some of the problems involved, are investigated in this option.

OPTION 3: ENERGY FOR LIFE Page 59



Photosynthesis is the process by which plants transform solar energy into a store of chemical energy—in the form of starch and/or sugar. This option describes how mankind and other animals are able to use this store. It also suggests some ways to improve food production.

OPTION 4: FINDING OUT ABOUT THE SUN Page 70



Although the Sun is about 150 million kilometres away from Earth, much is known about it. In this option you study sunlight and see how some of the information about the Sun has been obtained.

OPTION 5: WATTS UP THERE? Page 80



You know the Sun is radiating energy to the Earth. In this option you make an estimate of how much it radiates in one second.

(An option for those interested in measurement and maths.)

OPTION



Various stores of energy are available to mankind. In this option you read about these resources and discuss the problems associated with them.

The Earth's Energy Resources

THE HISTORY OF ENERGY



According to one legend of Greek mythology, the task of creating mankind was given to Epimetheus and his brother Prometheus. Epimetheus, before making man, gave the best gifts of protective covering—fur, feathers and shells—to the animals. They also received the gifts of courage, cunning, swiftness and strength. Too late Epimetheus realized his mistake—man was left naked and puny!

To make humans superior, Prometheus took over the task and fashioned them upright and more like the gods. Then he went to the Sun, lit a torch, and brought back fire for humans. This provided them with a means of protection far better than anything else.

Primitive people used fire for warmth and cooking. The ability of human beings to tap various sources of energy gave them an advantage over animals.

As well as being a source of heat energy for primitive people, fire provided protection against wild animals.

Wood is one of the Earth's solar energy resources (stores). As such it is still used today.

By diverting the energy flow from its usual path (see diagram, page 28) mankind has gradually captured a larger and larger share of the Earth's available energy.

Human beings have found ways to release solar energy from other stores, and to use it to assist them in their work only comparatively recently in their history.



This wall fresco shows Egyptians using oxen to pull ploughs.
(Photo by courtesy of Australian Institute of Archaeology.)

Indirectly, men released solar energy when they used horses or oxen. These animals obtained their energy from the food they ate. The animals used food energy when pulling a plough. However, animal power was limited.

Once it was realized that the energy of running water could be harnessed, new energy converters (machines to transform energy) were developed. Horizontal, and later vertical, water-wheels came into use. At first the wheels were used to grind corn. Later, water was used as the main source of energy for manufacturing. Another energy converter, the windmill, was developed during the twelfth century.

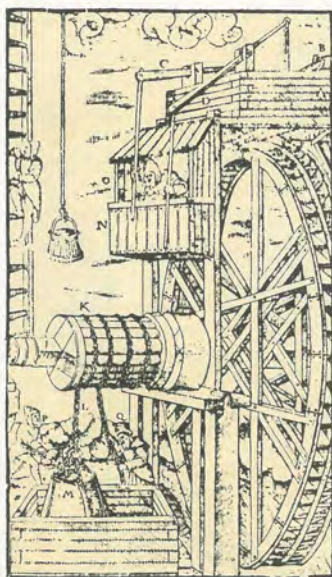
The location of early industrial centres was determined largely by the availability of wind and water power.



1.1 On page 13 of your record book, try to suggest any problems there would be in using only water-wheels and windmills as energy converters.

Not until the twelfth century did coal become a recognized source of energy in England. However, it is thought that the Chinese had used 'black rocks' for fuel for some thousands of years previously.

The need for pumps to remove water from coal mines led to the development of the steam engine. By the middle of the nineteenth century the steam engine was being used widely as a power supply for the manufacturing industry.



Wheel for raising water.
(From Agricola, *De re metallica*, Basle, 1556.)

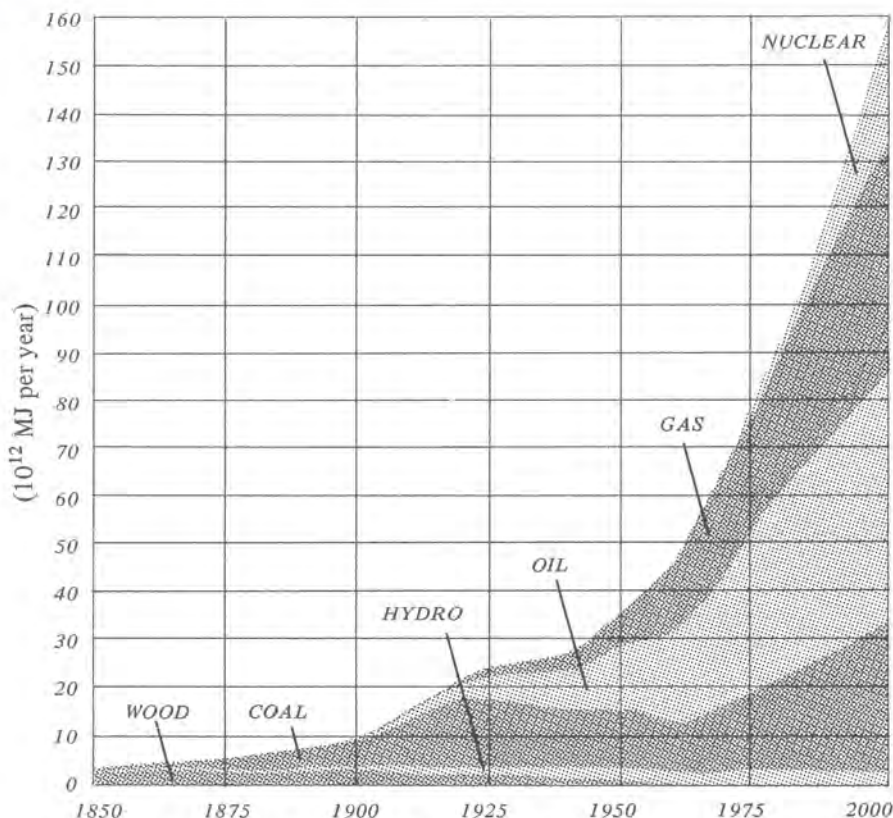


Since 1900 a steadily growing variety of energy converters, such as the internal combustion engine and the gas turbine, have been developed. The power output (the energy the machine can provide in a given time) from machines has increased steeply since 1700.

These improved machines have made the twentieth century one of accelerated energy use. Broadly speaking, it can be said that the energy needs of mankind for industrial purposes are doubling once every ten years.

1 megajoule (MJ) = 1 000 000 joules. This is roughly the energy given out by a one-bar electric radiator in 15 minutes.

FUEL CONSUMPTION PER YEAR IN USA



Adapted from *Energy and Power* by Chauncey Starr. © 1971, by Scientific American, Inc. All rights reserved.

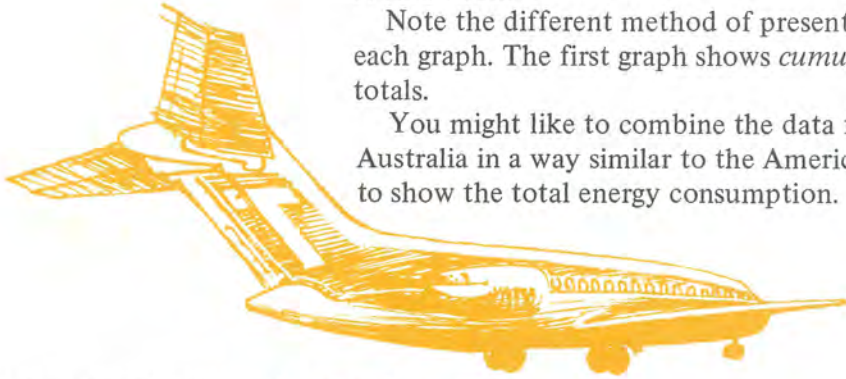


1.2 Study each of the graphs on these pages showing energy consumption. Then try to answer the questions on page 13 of your record book.

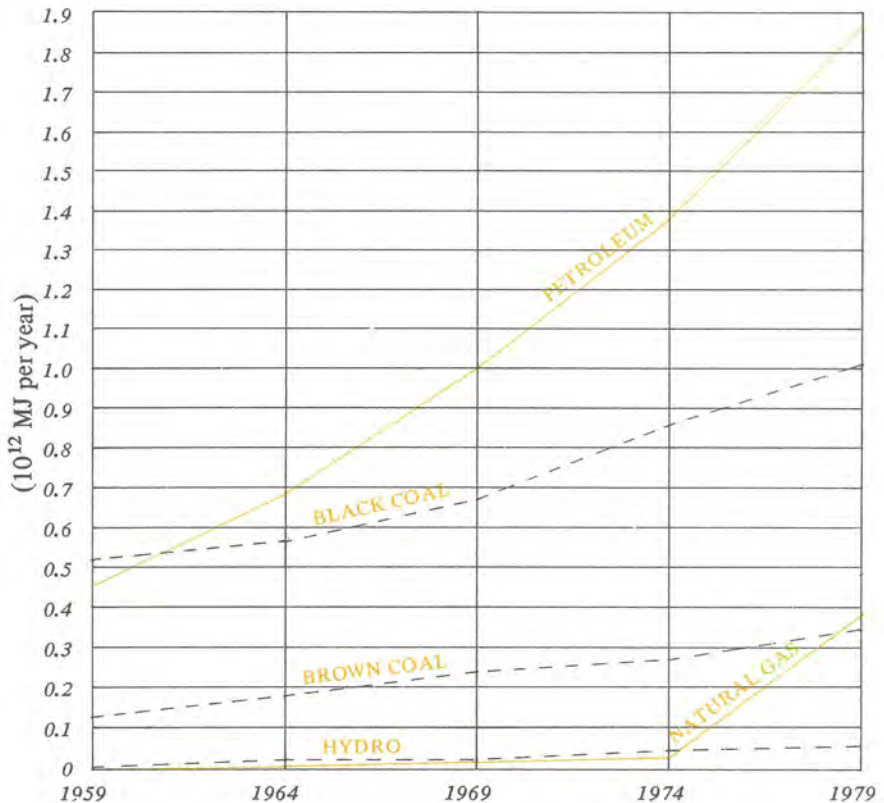
1

Note the different method of presentation of each graph. The first graph shows *cumulative* totals.

You might like to combine the data for Australia in a way similar to the American graph to show the total energy consumption.



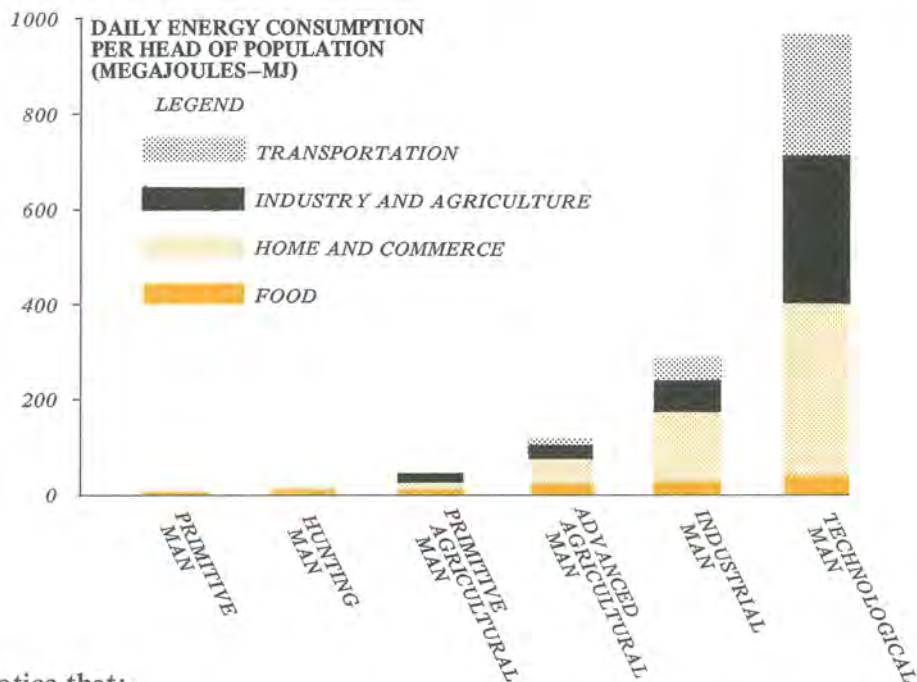
FUEL CONSUMPTION PER YEAR IN AUSTRALIA



Figures adapted from: Forecasts of Primary Energy Fuels, Department of National Development, 1972.

ENERGY CONSUMPTION THROUGH HISTORY

The graph below shows estimates of the daily energy consumption per head of population at six stages in the history of mankind. The accuracy is least for the early stages.



Notice that:

- ☐ Primitive people, without the use of fire, had only the energy of the food they ate (East Africa, 1 million years ago).
- ☐ Hunting people had more food and also used fire for heating and cooking (Europe, 100 000 years ago).
- ☐ Primitive, agricultural people grew crops and gained some energy from animals (5000 B.C.).
- ☐ Advanced agricultural people had some coal for heating, some water and wind power and animal transport (Europe, A.D. 1400).
- ☐ Industrial man had gained the steam engine (England, 1875).
- ☐ Technological man uses much of his energy in the form of electricity.

Adapted from Earl Cook, *The Flow of Energy in an Industrial Society*. © 1971, Scientific American, Inc. All rights reserved.

Due to the rapidly increasing use of energy without a similar increase in the sources of energy, mankind faces an energy crisis.

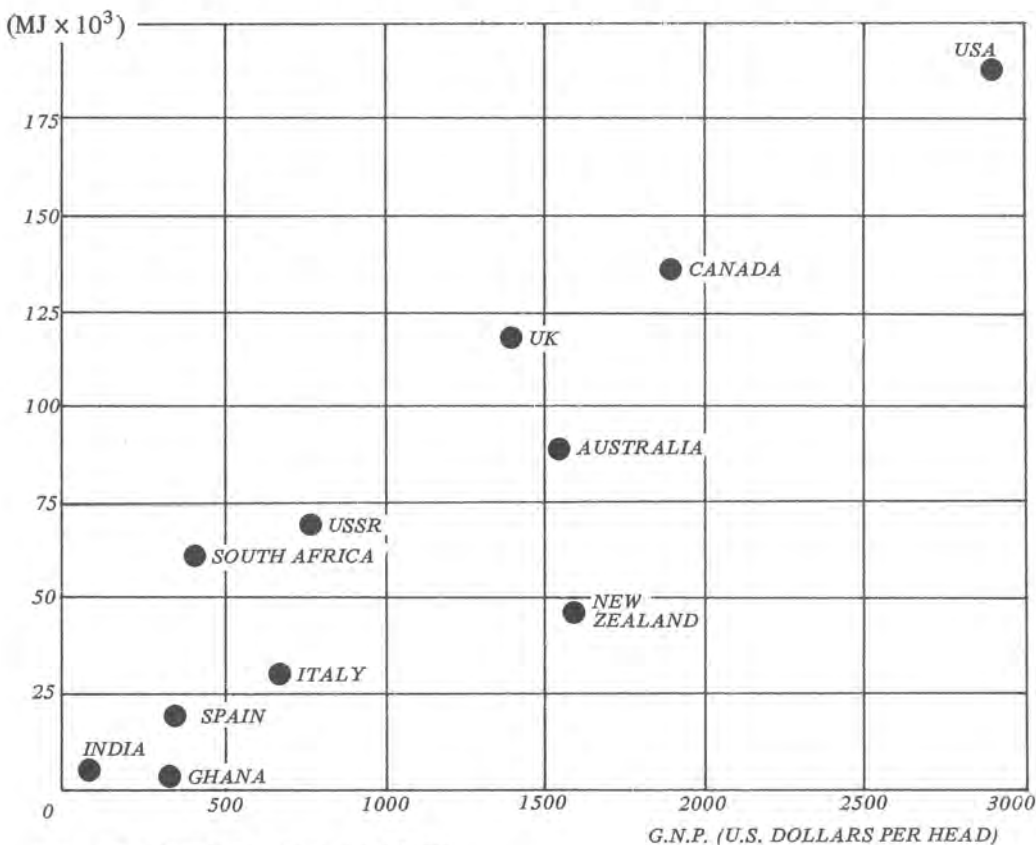
You may like to investigate the living conditions of people in any one of the periods listed above. A history teacher may help you.

ENERGY CONSUMPTION THROUGHOUT THE WORLD TODAY

1

The graph below shows the relationship between

- the energy used in one year per head of population, and
- the value of all materials produced by the country in the same year, per head of population. (This is called the gross national product—GNP.)



Also adapted from Cook, *The Flow of Energy*.



1.3 Look at the position occupied on the graph above by Australia and compare it with those of the USA and India. Why do you think they are in the positions shown? You could discuss this.



1.4 Compare a country which tends toward top left (for example, the United Kingdom) with one nearer the bottom right (for example, New Zealand). What are the main industries in each of these countries? How does this help explain their positions? (You may need to look up references to find the main industries in these countries.)

ENERGY SOURCES

FOSSIL FUELS

Look again at the graphs on energy consumption on pages 36 and 37. The fossil fuels listed—coal, oil and gas—make up by far the highest proportion of the energy resources.

It is difficult to estimate how long these resources can last. One figure quoted is that, from beginning to end, the span during which fossil fuels can be used on Earth will be 1300 years. Other estimates show that if increase of energy use continues at the present rate, about 80 per cent of the fuel will have been used over a span of only 300 years. And this is a resource which has taken 600 million years to accumulate! Obviously nature is not replacing the resources at the same rate as mankind is using them.

Additional problems arise out of the use of fossil fuels. For example, carbon dioxide and other gases as well as unburnt particles are released into the atmosphere when fossil fuels are burnt.



1.5 Discuss possible effects of this with others. Summarize suggestions in your record book. List all the opinions you can find. No one knows for sure what these effects are.

OTHER SOURCES

This section provides a brief summary of different energy sources. It contains suggestions for further research work. If you follow any of the suggestions there is space on pages 16 to 19 of your record book for your notes. You may, however, decide to join in with a group and prepare charts etc., to show to other students.

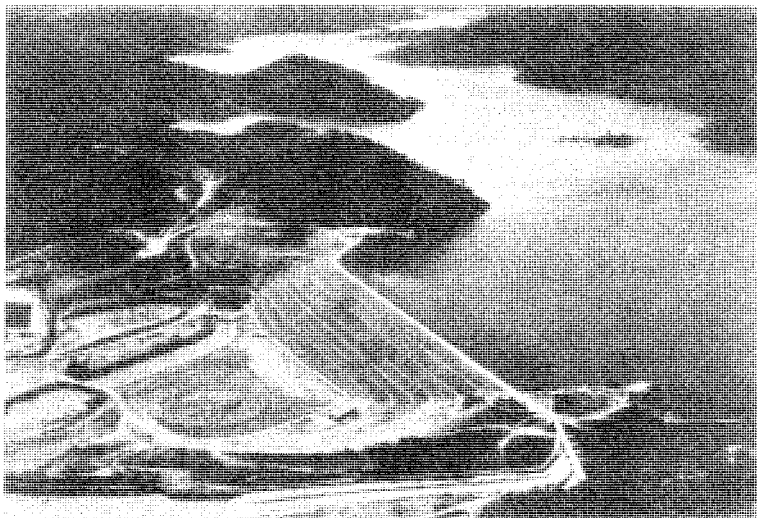
Energy from Tides and Wind

The energy of tides is used in some countries. In some areas the wind is harnessed.

You could find out more about these energy sources.

Hydro Electricity

Energy from water in dams is used in many countries. In Australia the Snowy Mountains Authority hydro scheme has been a success. You could research information on this and/or other Australian hydro schemes.

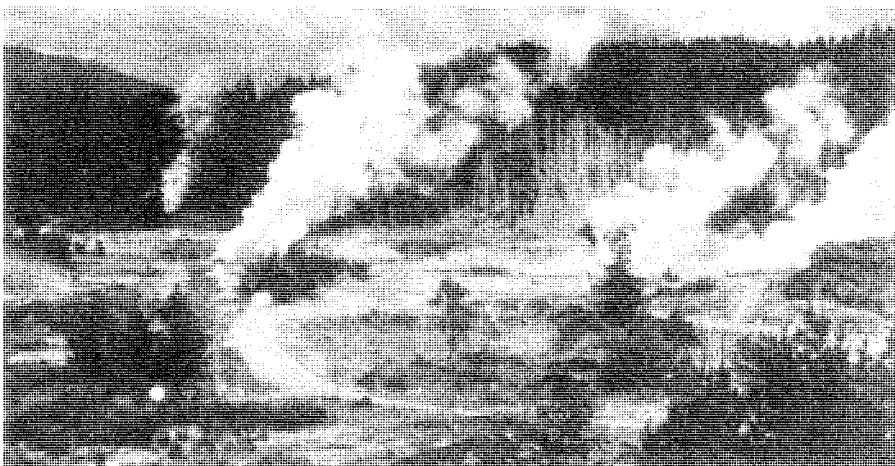


Eildon Reservoir. The lake created by damming a river is indirectly a store of solar energy. Can you see why?

(Photo by courtesy of State Rivers and Water Supply Commission of Victoria.)

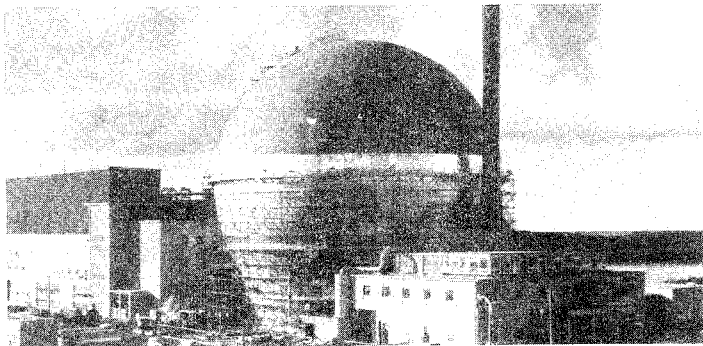
Geothermal Energy

Underground steam is an important source of energy in several parts of the world. What countries, other than New Zealand, use geothermal energy? What type of ground structure is common to these countries?



Geothermal energy steam condensers.

(Photo by courtesy of New Zealand Government Tourist Bureau.)



A nuclear power station.

(Photo by courtesy of United Kingdom Atomic Energy Commission.)

Nuclear Energy—Fission

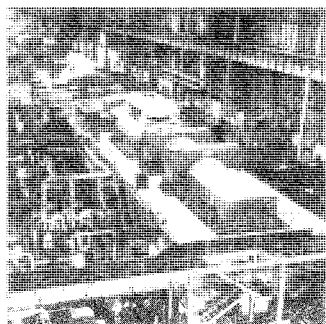
Nuclear reactors are supplying energy in some parts of the world. They release energy from special atoms (isotopes) of the element uranium.

Under certain conditions, these uranium atoms can be made to split into several fragments. This process, called **fission**, releases large amounts of energy. In nuclear power stations this fission energy released in reactors is used to boil water to produce steam which drives turbines for electricity generation.

In the 1950s the nuclear reactor was regarded as the answer to energy problems. One kilogram of uranium fuel could release enough energy to supply a city of about half a million people for a day. About 50 tonnes of coal would be needed to supply the same amount of energy.

However, the disposal of materials left over from the fission reaction poses a most serious problem. These materials are radio-active. They give off lethal radiation and will continue to do so for many years after use. So far the radio-active waste has been disposed of in concrete or other suitable containers buried deep underground or in the depths of the ocean. Is this good enough? Can this be done forever?

You could find out more about the fission process, nuclear reactors and disposal of radio-active waste. You will need a knowledge of terms like **nucleus**, **radio-activity**, **isotopes**, **neutrons** and **moderators**. You could also obtain information on the dangers of radiation.



Steam turbines for electricity generation.

Nuclear Energy—Fusion

Some atoms can be made to join together (fuse) to form different atoms. (This process is very different from the formation of chemical compounds.) When **fusion** occurs, vast amounts of energy are released. Solar energy, for example, comes from the fusion process in the extremely hot interior of the Sun.

In the super-destructive hydrogen bomb, special hydrogen atoms (deuterium) fuse in a fraction of a second and release enormous quantities of energy.

So far nobody has succeeded in setting this energy free in a slow, controlled manner. It is believed the fusion process would be highly desirable because:

- The special hydrogen atoms used as ‘fuel’ occur in sea water—a cheap, inexhaustible source.
- One tonne of this ‘fuel’ would supply a large city for a year.
- No harmful waste substances are formed during the fusion process.

Many big research establishments are attempting to solve the control problem, so perhaps in the near future another vast energy supply will be available.

A more detailed study of fusion involves an understanding of the terms **nucleus**, **isotopes**, **heavy water**, **plasma** and others. You may like to read more about the fusion process.

HEAT IS A PROBLEM

Many fuels are likely to ‘run out’, but shortage of supply is not the only problem. A great deal of energy is wasted.



1.6 Petrol, a store of energy, is placed in the petrol tank of a car. The car is then driven along a flat road until it runs out of petrol and stops. What has happened to the energy that was stored in the petrol? Where does it go?

A similar situation exists when you look at the energy needed to generate electricity. In 1970, the USA (the greatest consumer) used about ten per



*Cooling towers at
Yallourn West
power station.*

*(Photo by courtesy of
State Electricity
Commission of Victoria.)*

WHAT OF THE FUTURE?

cent of all energy as electricity. About 25 per cent of the energy resources used up that year were needed to produce this electricity.

One estimate is that by the year 2000 half of the energy reserves will have been used up as heat for power stations.

In cooling towers like those shown at left, steam that has passed through power station turbines can be condensed and recycled for further use. Water from rivers, lakes or oceans is used as the cooling agent. This water is returned into the river, lake or ocean at a higher temperature.



1.7 What problems could arise from this procedure? Suggest ways in which this heat energy could be used.

Much of the heat energy released by the activities of mankind is radiated away from the Earth. The city of Moscow radiates three times as much heat as it receives from the Sun. New York radiates seven times as much. You might well ask if mankind should not be trying to use this heat energy by recycling it.

①

X As a result of discussions and interpretations of graphs in this option you are probably aware of the estimated future world demand for energy. For a long time fossil fuels have supplied most of the energy needed by mankind.

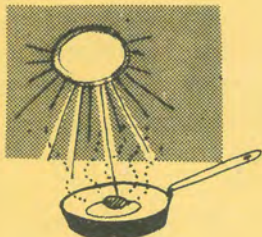
Inevitably, fossil fuels will be exhausted.

What can be done to meet future energy needs of mankind?

If you have looked into the feasibility of other energy sources, you may be in a position to judge their possible usefulness. (Don't forget cost.)

You might also ask what is being done about trapping the Sun's energy. You have seen that a solar cell can transform solar energy directly into electricity. At present these cells are far too expensive for large-scale use. Other ways of trapping solar energy are outlined in Option 2 (Direct Use of Solar Energy).

OPTION



Under certain circumstances and in certain areas direct solar energy could be a very desirable energy supply. How to tap this supply, and some of the problems involved, are investigated in this option.

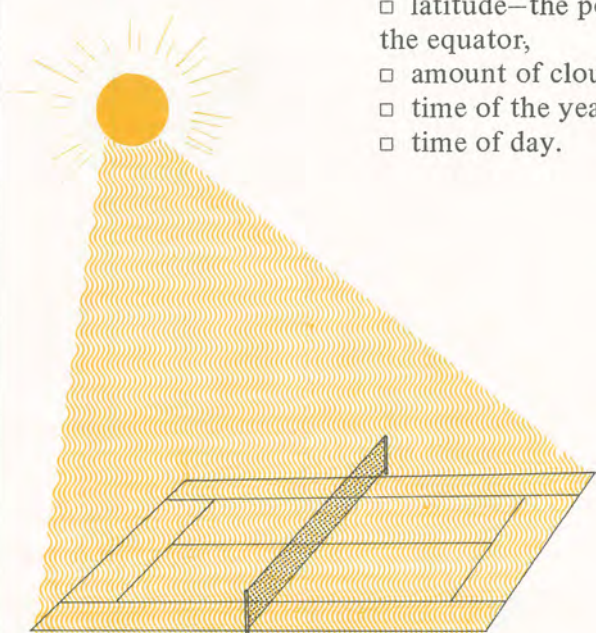
2

Direct Use of Solar Energy

During one clear day the solar energy falling on an area roughly the size of a tennis court, near the equator, is about equal to the energy in 135 litres of petrol or 180 kilograms of coal. Various factors alter the amount of energy received at places on the Earth's surface.

These factors include:

- ☐ latitude—the position of a place in relation to the equator,
- ☐ amount of cloud cover,
- ☐ time of the year, and
- ☐ time of day.



=



or





*A pyranometer—an instrument used for solar energy measurement.
(Photo by courtesy of CSIRO.)*

The supply of energy is not continuous, nor can it be guaranteed from one day to the next.

Though the supply at any given time and place is uncertain, average yields can be predicted with reasonable accuracy in countries keeping meteorological records.

The table below gives an indication of the daily average (taken over 1 year) of solar radiation falling on 1 square metre of surface in various parts of the world. The energy is measured in megajoules (millions of joules).*

Consider the 22 megajoules given as a top figure for Australia. If all this energy falling on an area of 1 square metre in 1 day could be transformed to electricity, it would:

- keep a one-bar radiator operating for about 5 to 6 hours.
- provide about one-third of the energy needed to heat an average household hot water tank from room temperature to about 70°C.

* 1 megajoule (MJ) = 1 000 000 joules. This is roughly the energy given out by a one-bar electric radiator in 1½ minutes.

LOCATIONS THROUGHOUT THE WORLD	DAILY AVERAGE SOLAR RADIATION (megajoules per square metre)	AUSTRALIAN LOCATIONS	DAILY AVERAGE SOLAR RADIATION (megajoules per square metre)
Australia	16–22	Adelaide	17
Europe	7–14	Brisbane	18
India and Pakistan	19–23	Birdsville, Q	21
Sahara Desert	23	Cairns, Q	19
United States of America	14–21	Carnarvon, WA	22
		Cobar, NSW	20
		Marree, SA	20
		Melbourne	16
		Perth	19
		Sydney	16
		Woomera, SA	20

(Data by courtesy of Mr H. de Bruin, Flinders University.)



2

Harvesting salt by a modern method.

(Photo by courtesy of Dominion Salt Ltd, Lake Grassmere, Marlborough, N.Z.)

①

Direct use of solar energy by people is not a new idea. For centuries salt has been extracted from sea-water by evaporation. Food has been preserved by drying it in the sunlight. Bricks for homes are sun-dried in some countries (including Australia).

Solar energy is already being used as a heat supply in some homes in some parts of Australia.

In general, solar radiation may be

- ☐ absorbed by a surface, or
- ☐ concentrated by focusing it with mirrors or a lens.

You can now find out something about both these methods.



A lens focuses heat and light to act as a 'burning glass'.



A solar still at Coober Pedy, SA.

(Photo by courtesy of CSIRO.)

WHEN SOLAR RADIATION IS ABSORBED BY A SURFACE . . .

SOLAR STILLS (distillation plants)

You found out in *What Is Solar Energy?* that a blackened thermometer bulb absorbed energy and became warmer than a shiny bulb.

The knowledge that black surfaces absorb heat can be put to use in solar stills.

Water from bores in outback districts of Australia is frequently salty and needs purifying before it can be used as drinking water. Solar stills can produce purified water from such supplies for small townships and isolated motels.

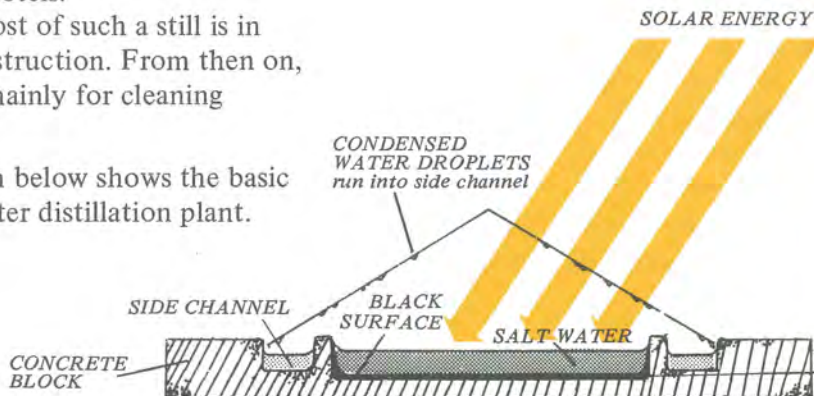
The main cost of such a still is in the initial construction. From then on, the costs are mainly for cleaning and repairs.

The diagram below shows the basic design of a water distillation plant.

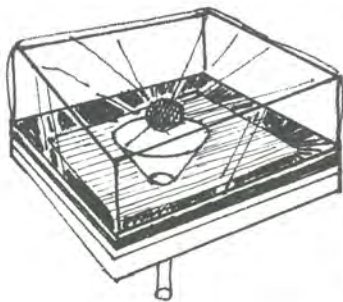
The photo above shows a type of water distillation plant commonly used in Australia.

Three basic ideas apply in the design of a solar still:

- 1 the glass cover produces a 'glasshouse effect' (see page 26),
- 2 the black surfaces absorb radiation and become warm, vaporizing some water, and
- 3 the water vapour condenses on the cooler glass faces.



ACTIVITY 1: CONSTRUCTING A SOLAR STILL



Using the three basic ideas on page 48, you could construct a small solar still and leave it in the sunlight for several days. You do not need to use any of the designs shown at left or the materials listed. Clear plastic can be used instead of glass. Black polythene makes a suitable absorbing surface. It is important to keep the still sealed as far as possible to stop water vapour escaping.

2

The materials you need will depend on the design you choose. You will probably use some or all of the following:

- black polythene sheet
- clear polythene sheet
- 1 sheet of glass, about 30 cm x 30 cm
- 1 glass jar with lid
- 1 blackened tin—to fit inside glass jar
- aluminium foil
- 1 roll of adhesive tape
- 1 length of wire, about 3 metres—for constructing frame
- 1 cardboard box, about 30 cm x 30 cm
- slats of wood of various sizes
- 1 narrow-necked container to collect distilled water
- 1 funnel.



2.1 On page 21 of your record book, write a report describing the solar still you constructed. Include a simple labelled diagram.

If you do not get any purified water during the days your still is being tested, there could be a fault in your design. What improvements would you suggest? Try them and record the result.

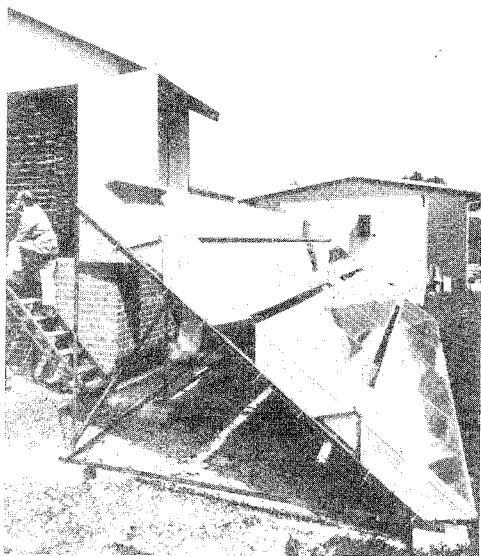
Make notes in your record book about any changes you make—and record whether they are successful or not.



Students with 'their' solar still.

SOLAR HEATING BY ABSORPTION

The basic ideas for solar heating by the absorption method are similar to those for solar stills.



*A pilot solar-heated kiln.
(Photo by courtesy of CSIRO.)*

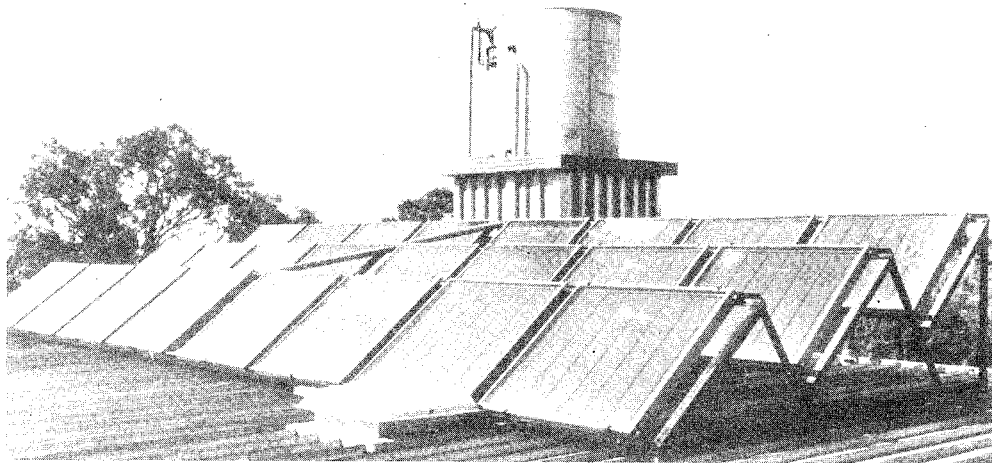
The photo at left shows a timber kiln which is being heated by solar energy—to reduce the water content of the timber. In this case, hot air is circulating rather than water.

Air heated this way by solar energy can be used to heat a house. Any energy not immediately required can be used to heat a pile of rocks built under the house structure. The heat store (the rock pile) warms the house. The timber kiln has such a rock pile built into its brick base.

The photo below shows absorbing surfaces and storage tank for the heated water of a solar heating system.



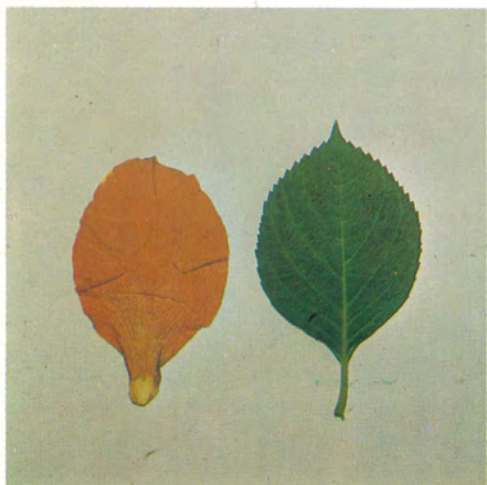
2.2 Why are the storage tanks and the kiln in the photos at a higher level than the absorbing surfaces? Why is the pile of rocks built under the kiln? You may like to discuss these questions with others before writing your answers.



*Solar water heaters at a youth hostel, Griffith, NSW.
(Photo by courtesy of CSIRO.)*



Two examples of the effect of a prism on white light.

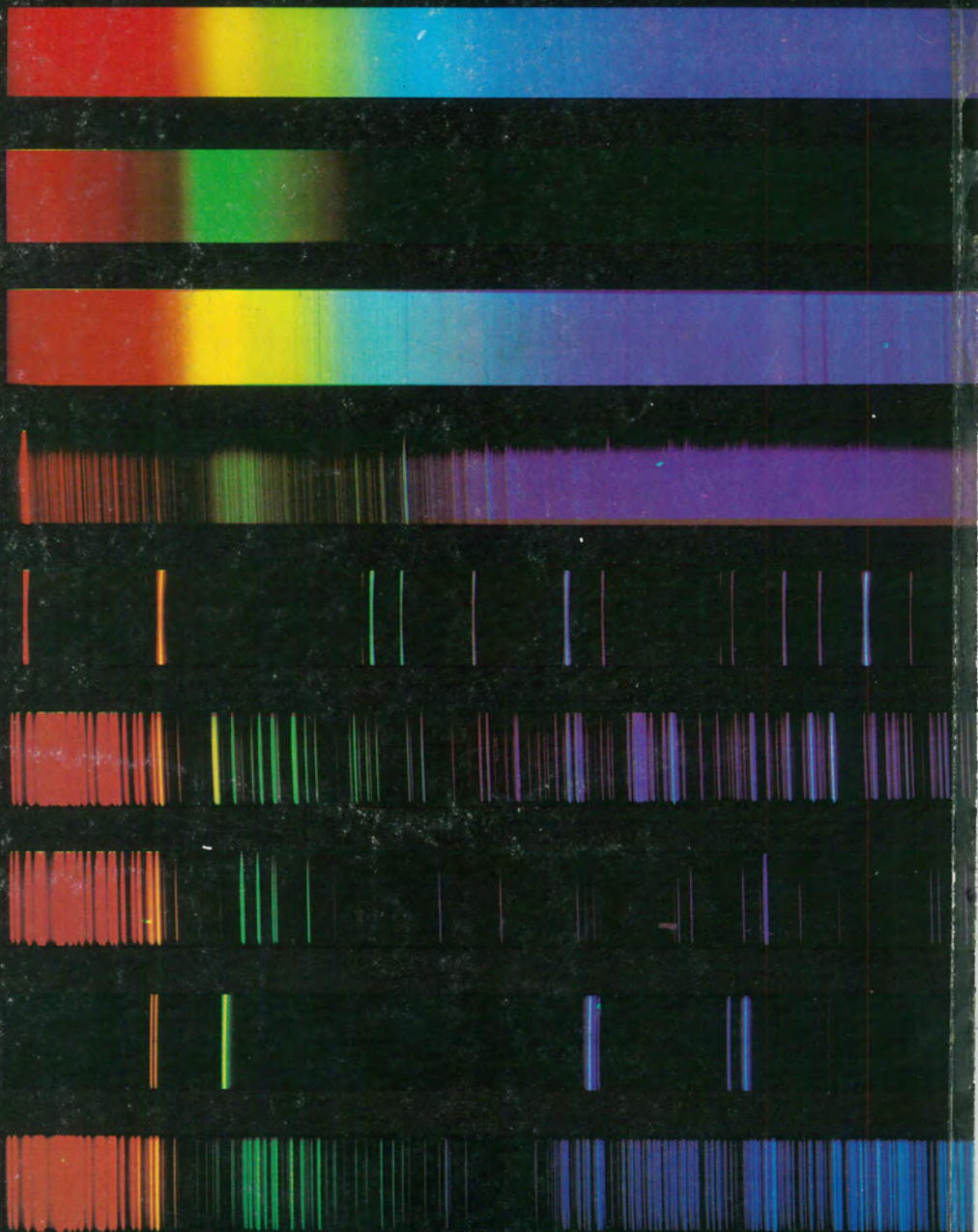


Flower-petal and green leaf.



The petal and the leaf placed in the spectrum of white light.

SPECTRA



(Spectra were supplied by courtesy of Dr P. Thistlethwaite, Department of Chemistry)



Continuous spectrum of white light.

The spectrum obtained after passing white light through chlorophyll solution.

The spectrum of sunlight showing Fraunhofer lines.

LIGHT IS EMITTED BY GASES OR VAPOURS UNDER SPECIAL CONDITIONS.

The spectrum of light emitted from hydrogen gas.

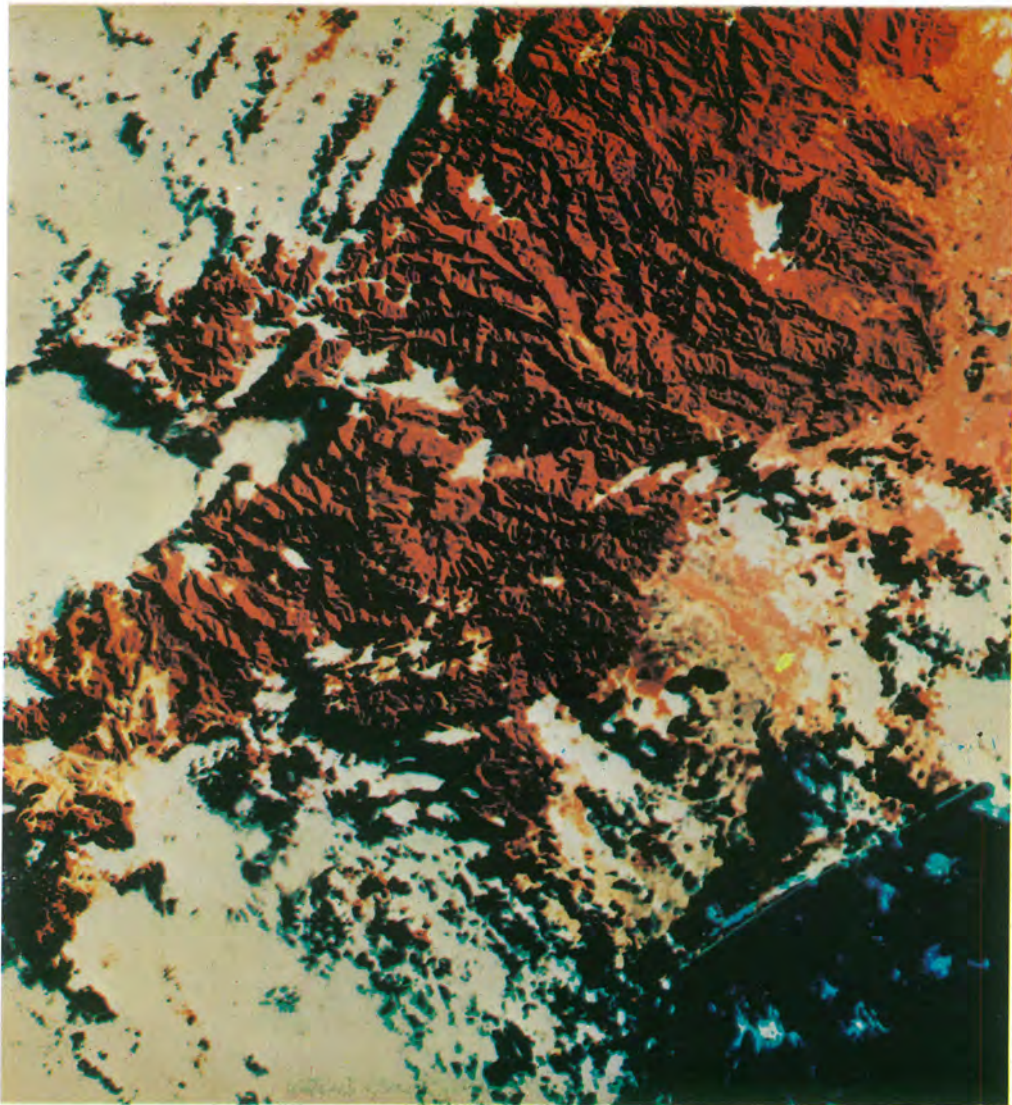
The spectrum of light emitted from helium gas.

The spectrum of light emitted from calcium vapour.

The spectrum of light emitted from a mixture of sodium and potassium vapours.

The spectrum of light emitted from mercury vapour.

The spectrum of light emitted from iron vapour.



A colour composite photograph taken from the Earth Resources Technology Satellite-1 ('ERTS-1) from an altitude of about 1000 kilometres on 27 August 1972. Three colours—green, red and infra-red—were seen and recorded separately by the satellite and combined at the American NASA centre.

Healthy crops, trees and other green plants, which are very bright on infra-red sensitive film, but invisible at that height to the naked eye, are shown as red. Areas with sparse vegetation appear as light orange, and barren land as light grey. Cities and industrial areas show as green or dark grey, and clear water is blue or black. The white patches are clouds.

The following geographical landmarks are included in the photograph.

Australian Alps (lower left to top right)

Lakes Entrance (lower right centre)

Tasman Sea (lower right)

Bairnsdale (lower centre)

Ninety Mile Beach (lower right)

(Photo by courtesy of NASA.)

ACTIVITY 2: CONSTRUCTING A SOLAR WATER HEATER

You can set up some simple equipment to find out more about how a solar water heater works.

You will need:

- 1 large test-tube
- 1 length of 'large' glass tubing, about 2.5 cm x 17 cm diameter—a large test-tube with the bottom cut off would do
- 1 tin of flat black paint
- 1 small paint brush
- coloured water
- 1 thermometer, -10°C to 110°C
- 1 stand with 2 clamps
- 2 lengths of glass tubing, fitted into 2 two-hole rubber stoppers—as shown at left

2

If you can not obtain fitted tubing you will need the following equipment:

- 2 two-hole rubber stoppers to fit the test-tube and 'large' glass tubing
- one 40-cm length of glass tubing with outside diameter to fit the holes in the stoppers, and internal diameter of about 0.5 cm
- 1 glass-cutting knife (or file).

Cut the tubing into two lengths. (The size of each will depend on the lengths of the test-tube and the 'large' tubing.) Fit the two lengths into the stoppers as shown at left.

Cutting glass tubing and fitting it into stoppers requires considerable skill. If you haven't done either before, seek advice from a teacher.

Fill the test-tube to over-flowing with the coloured water. Carefully slide the stopper and tubing into the test-tube. Avoid air bubbles.

Now put the top tube in position and fill it with cold water (not coloured).

Paint the test-tube black.

Place the equipment in direct sunlight and watch to see if there are any changes. Use the thermometer to measure the temperature of the water in the top tube at regular intervals over a period of time.



2.3 Write a short report about your solar water heater. Include details of measurements you made, and any suggested improvements.

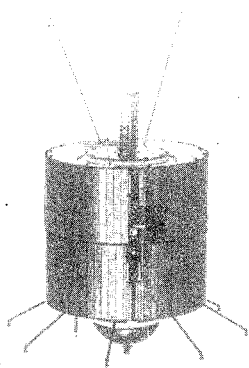
SELECTIVE ABSORBERS

You have used black surfaces to absorb energy. Early experiments in this field were also done with black surfaces. They are good absorbers, but there is a problem. Black surfaces also emit energy readily.

Recent work at the University of Arizona, in the United States of America, by Professor and Mrs Meinel has possibly solved this problem. The professor and his wife found that polished metal surfaces became absorbers when they were covered with other thin, special layers. Such layers work much like the glass in a glasshouse. They let in the higher energy radiation, but trap the lower energy radiation from the heated interior inside. That is, they select the type of radiation they let through.

It may be possible to use these absorbers in solar power generation. For example, desert areas could be covered with selective absorber panels. The absorbed heat could be used to produce steam to drive electric generators.

THE SOLAR CELL



At present, using solar cells is an expensive method of producing electricity from solar energy.

However, for special purposes such as providing power for satellites, solar cells are very useful—and considered well worth the cost.

A recent break-through in the United States has shown that the pure form of silicon needed for making solar cells can be produced much more cheaply than it is now.

*A solar-cell powered satellite.
(Photo by courtesy of NASA.)*

STORAGE

Solar cells and selective absorbers will be useful in the production of electricity only as long as the Sun is shining. What can be done on dull days or at night?

The storage of electrical energy is not easy. Some energy can be stored as chemical energy in lead accumulators like the batteries used in cars.

Another suggestion which is being discussed widely is to use electricity, while it is being generated, to decompose water into its elements—hydrogen and oxygen. These gases can be stored and transported. By recombining the elements in an energy-convertor called a fuel cell, electricity could be generated directly. Alternatively, burning the gases, as in a rocket engine, could provide hot gases to operate a generator.

WHEN SOLAR RADIATION IS CONCENTRATED . . .

2

Stories about the use of solar radiation go back thousands of years. The noted Greek mathematician, Archimedes (c. 287–212 B.C.), is said to have used solar energy to delay a Roman fleet when it attacked his birthplace of Syracuse, in Sicily. He focused solar radiation from curved reflectors on to the sails of the attacking ships, causing them to catch fire.

The photo below shows a present-day reflector. Solar radiation is reflected from the plane mirror up to the curved reflector which concentrates the radiation on to a very small area (focus). The temperatures there are very high.

The reflector is used mainly for research purposes. It can heat substances to very high temperatures without introducing the impurities that occur when flames are used for heating.



(Photo by courtesy of the School of Physics, University of New South Wales.)

ACTIVITY 3: BUILDING A SOLAR REFLECTOR

You can make your own reflector to concentrate radiation.

The shape of the reflecting surface is important. For accurate work all reflected radiation should meet at a point.

To find the best shape, you will need:

- 1 sheet of cardboard, about 20 cm x 20 cm
- 1 sheet of aluminium foil, about 20 cm x 20 cm
- 1 roll of adhesive tape.

Stick the sheet of aluminium foil on to the piece of cardboard. Bend the cardboard and use the adhesive tape to keep its shape.

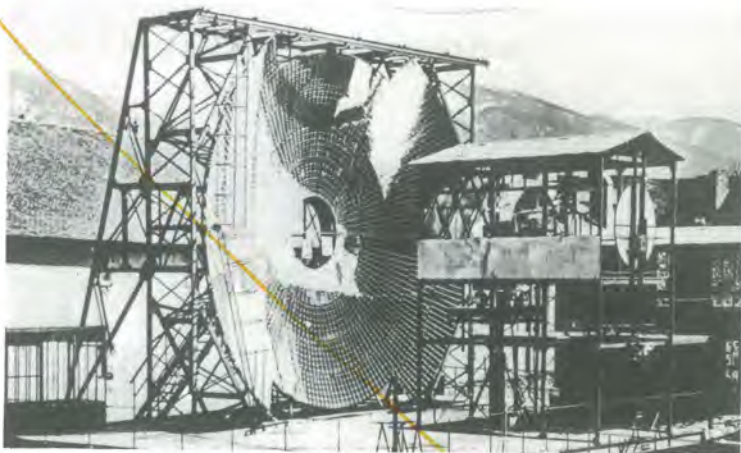
Out of doors, face your reflector toward the Sun. With care, place a strip of paper in various positions in the centre of the reflector.

Can you make the reflected sunlight form a small bright line on the paper? You may have to try several different curvatures of your cardboard.

When the reflected sunlight forms a small bright line on the paper, hold the paper steady.

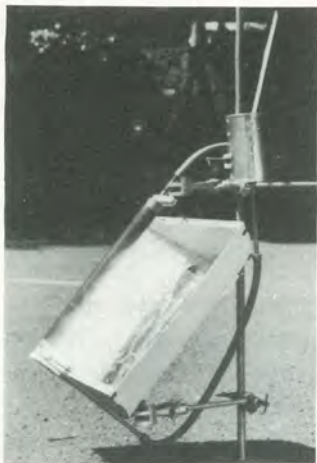


2.4 What happens to the paper? Why? (If you can't find the correct shape to focus the Sun's rays, turn to Check Your Answers, page 93.)



Parabolic reflector at Odeillo, in the Pyrenees mountains, France.

ACTIVITY 4: BUILDING A SOLAR REFLECTOR WATER HEATER



A model solar reflector water heater.

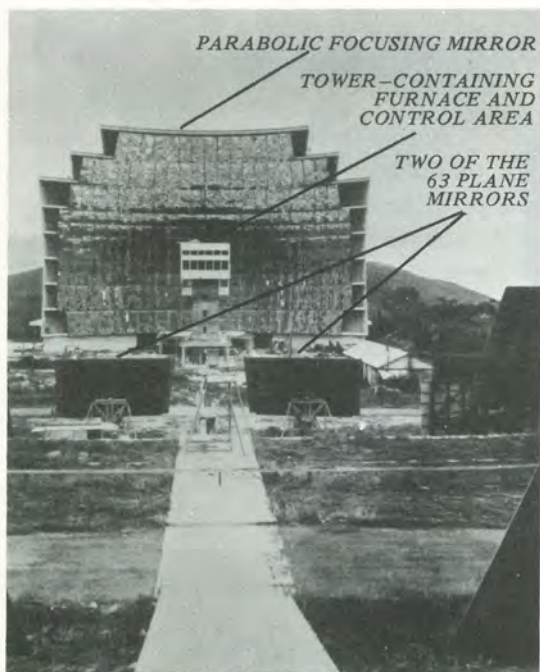
The photo at left shows a model solar water heater. It uses a **parabolic reflector** to control solar radiation.

You could build your own model solar water heater.



2.5 If you build one, give details of its construction **2** and performance. There is space for this on page 24 of your record book.

A GIANT SOLAR HEATER (furnace)



Solar furnace at Odeillo.

(Photos by courtesy of the Press and Information Service, French Embassy, ACT.)

The photo at left shows an experimental solar furnace built in the Pyrenees mountains in France. The project started in 1969 and was financed by the French National Centre for Scientific Research.

Details of the Furnace

Cost: About \$A. 6 000 000

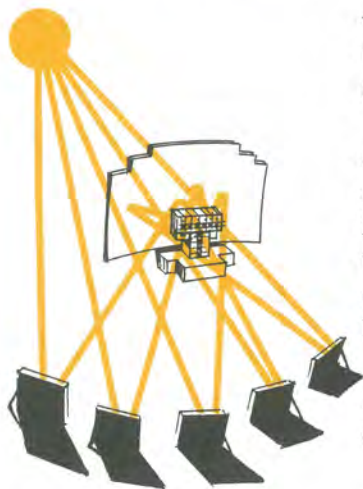
Parabolic Focusing Mirror:

- contains 9000 individually shaped mirrors (facets) to give desired curvature
- covers an area of about 600 square metres
- has a focal length of about 17 metres.

Plane Mirrors:

- each has a surface area of about 13 square metres
- each contains 180 individually shaped facets.

Working the Odeillo Furnace



There are 63 plane mirrors. They can be moved vertically and horizontally to follow the path of the Sun. In this way solar radiation can be directed continuously at the parabolic focusing mirror.

In theory, with all plane mirrors correctly aligned, 16 000 images of the Sun can be focused on the solar furnace, which is about 1.8 metres inside the tower. This produces temperatures up to 3800°C in the furnace. Depending on how much energy is required any number of plane mirrors can be brought into operation.

Huge stainless steel shutters keep out the focused solar radiation until needed. (Polished stainless steel reflects the incoming radiation.)

The materials produced in a solar furnace are of greater purity than those produced in any other type of furnace. Even though the solar process is costly, the use of very pure materials is becoming more and more important in industry.

CAN THE SUN END THE WORLD'S ENERGY WORRIES?

① *



*Experimental solar cooker.
(Photo by courtesy of Engineering Experiment
Station, The University of Wisconsin.)*

People throughout the world know that one day there will be no more fossil fuel as a source of energy.

Overcoming the problems of containing and using nuclear fusion as an energy source may solve the energy crisis. Can technology do this in time? Some scientists believe it can.

Others are turning more and more to the possibilities of solar energy. Professor J.O'M. Bockris of the Flinders University of South Australia envisaged Australia as a world leader in the supply of solar energy.

Consider the plans and suggestions in this section, then discuss with other students what you think about the possibilities for Australia.

AN AUSTRALIAN PIPE DREAM?

Australia has in reserve:

- a plentiful supply of free sunshine,
- hectares and hectares of unused, barren land on which the Sun shines, and
- a possible vast supply of subterranean water under the barren land.

Methods by Which These Reserves Can Be Put To Use



2

The above methods are effective only during the day when the Sun is shining.

Problems

At the moment there are two main problems:

- present cost of converters, and
- development of suitable storage systems.

Catering for Night-time Needs

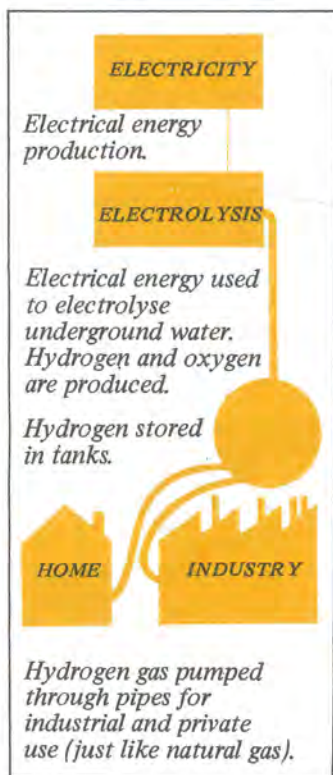
To cater for night-time uses, energy must be stored.

The electricity (or some of it) produced by the methods suggested above could be used in the shown in the diagram at left.

In homes and industry fuel cells could reconvert hydrogen to electricity.

A by-product of using hydrogen in fuel cells is pure water. This could be used for drinking purposes.

Selective solar absorbers could also be placed on roofs and walls of buildings to provide heating and cooling (find out how a refrigerator works).



Professor Bockris's Calculations

Professor Bockris calculated that:

- 1 if solar cells convert about 10 per cent of incident energy to electricity (are 10 per cent efficient), and
- 2 the electrolysis process is 60 per cent efficient,
- 3 the reconversion by the fuel cell would be 60 per cent efficient, and
- 4 if these are reasonable estimates, then an area of about 2500 square kilometres could supply Australia's energy requirements.

Two thousand five hundred square kilometres is the space contained within a square of sides 50 kilometres in length. If you find it hard to imagine how much space this really is, try the following procedure.

Obtain a scale map of Australia. From the scale find the length that corresponds to 50 kilometres. Draw a square of sides equivalent to 50 kilometres and place it on the map.

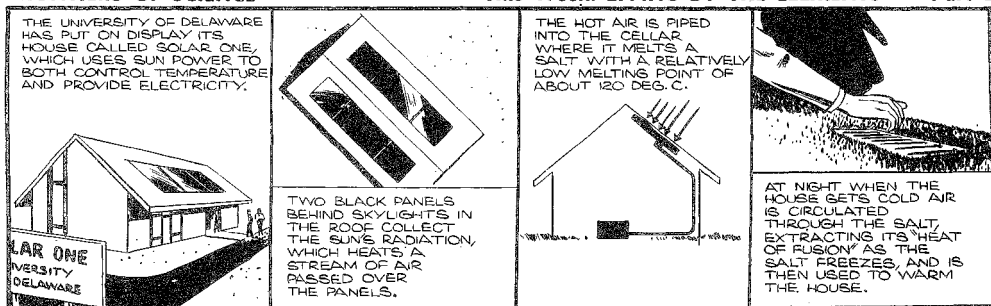
(Many outback stations are much larger than 2500 square kilometres.)

Several 'solar farms' could possibly provide energy for export.

In this option you have seen some of the possible uses for solar energy. At the moment the cost of equipment capable of using solar energy is high when compared with costs for equipment using fossil or nuclear fuels. A great deal of research and development needs to be done. But what of the future?

FRONTIERS OF SCIENCE

This Week: LIVING BY THE ELEMENTS -- Part 2



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OPTION



Photosynthesis is the process by which plants transform solar energy into a store of chemical energy—in the form of starch and/or sugar. This option describes how mankind and other animals are able to use this store. It also suggests ways to improve food production.

Energy for Life

The starch which plants can produce is sometimes stored in special places, for example, seeds (cereals), fruits (bananas) or tubers (potatoes). Mankind has used this starch for a long time to supply energy needs.

You begin this option by investigating some of the conditions necessary for starch formation. To do this you will need to be able to do a simple test for starch.

3

ACTIVITY 1: A SIMPLE TEST FOR STARCH

You will need:

- 1 dropper
- iodine solution
- $\frac{1}{4}$ teaspoonful of starch
- 1 microscope slide.

Place a small quantity of starch on the slide. Add one drop of iodine solution to the starch. Note any colour change.

This is a very sensitive test. Even very low concentrations of starch will give this colour. However, if the starch is in a green leaf, there is one problem. The chlorophyll may mask any colour change—so you will need to remove it first. (See page 24.)

You can now try to find out what plants need to produce starch. You could begin by checking whether they need light energy.



In Activity 3 you will need to use leaves of plants which have been in light for several hours immediately before you test them. Keep this in mind while you are doing Activity 2—to avoid delay when you get to Activity 3. You will need variegated leaves—those with patches of green and yellow, or green and white, or both.

ACTIVITY 2: IS LIGHT ENERGY ESSENTIAL?

③

In this activity you can design your own investigation.

Discuss with others how you could best use a pot of plants to try to answer the question.

Remember that whatever you do, **light** must be the only possible factor (condition) likely to affect your results; that is, you need controlled conditions. You may need more than one pot of plants.

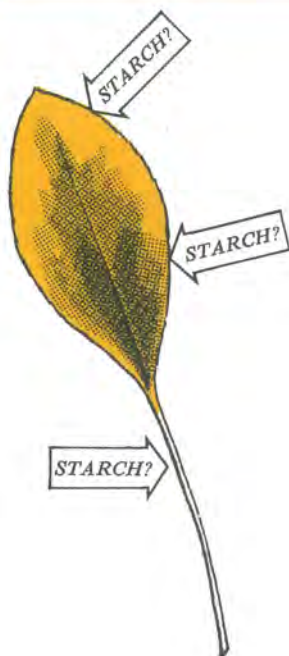
Once you have decided what you will do, discuss your plans with a teacher. Then set up your investigation.



3.1 On page 25 of your record book write an outline of your planned investigation. You may prefer to make sketches and label them. Later, note what you find out. When you are testing for starch, it is best to use a young leaf. Record all your results and try to explain them.

Light is only one factor to be investigated when finding out about solar energy stores in plants. You may think of others. Just how important is chlorophyll, for example? You can find out more about chlorophyll in Activity 3.

ACTIVITY 3: IS CHLOROPHYLL ESSENTIAL?



Some plants have leaves which have a pattern of green and yellow, or green and white, rather than being green all over. Do the non-green areas produce starch?

To try to find out you will need:

- access to a plant with variegated leaves, and
- the materials needed for testing leaves for starch.

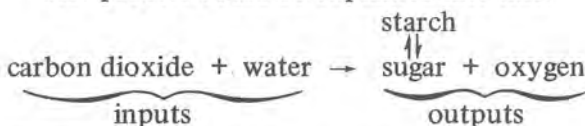
Discuss with others the method you would use to check the need for chlorophyll. Does your method control conditions, so that there will be no doubt, one way or the other, about chlorophyll's importance?



3.2 Make a record of your planned investigation. Draw diagrams, if necessary, to explain your method. Record the results of your tests. What conclusions can you draw from them?

The name given to the chemical changes taking place in a green plant and leading to the production of substances such as sugars and starch is photosynthesis*.

This process could be explained like this:



3.3 What other factors must be present for these outputs to take place?

Investigations have shown that photosynthesis is a complex process, involving a number of steps. These steps start with the absorption of light by chlorophyll, and lead eventually to the production of sugars and starch. Continued research is being done into the exact nature of the intermediate steps. Any variation in sunlight, moisture, temperature and other conditions affects photosynthesis, and therefore plant growth.

* From the Greek words *photos*, meaning 'light', and *synthesis*, meaning 'a putting together'.

OTHER INVESTIGATIONS



What happens if plants are grown in light of one particular colour? You will need some coloured filters. Don't forget a control experiment.



The green plant stores substances which contain the element carbon. Is carbon dioxide in the air the source of the carbon? One of your first tasks is to find a substance to absorb carbon dioxide.

What is pig power?



Have you noticed bubbles rising from certain weeds growing under water? What is this gas? Has it anything to do with photosynthesis?

ACTIVITY 4: THE ENERGY TRAP

Only about 25 per cent of the solar radiation falling on Earth is energy which is suitable for absorption by chlorophyll. Only a very small fraction of this energy is finally stored in green plants. Plants trap an average of 0.2 per cent (one part in 500) of the radiation. Some of this energy is used to maintain the plant and some of it is stored. It is on this stored energy that so many of mankind's energy needs depend.

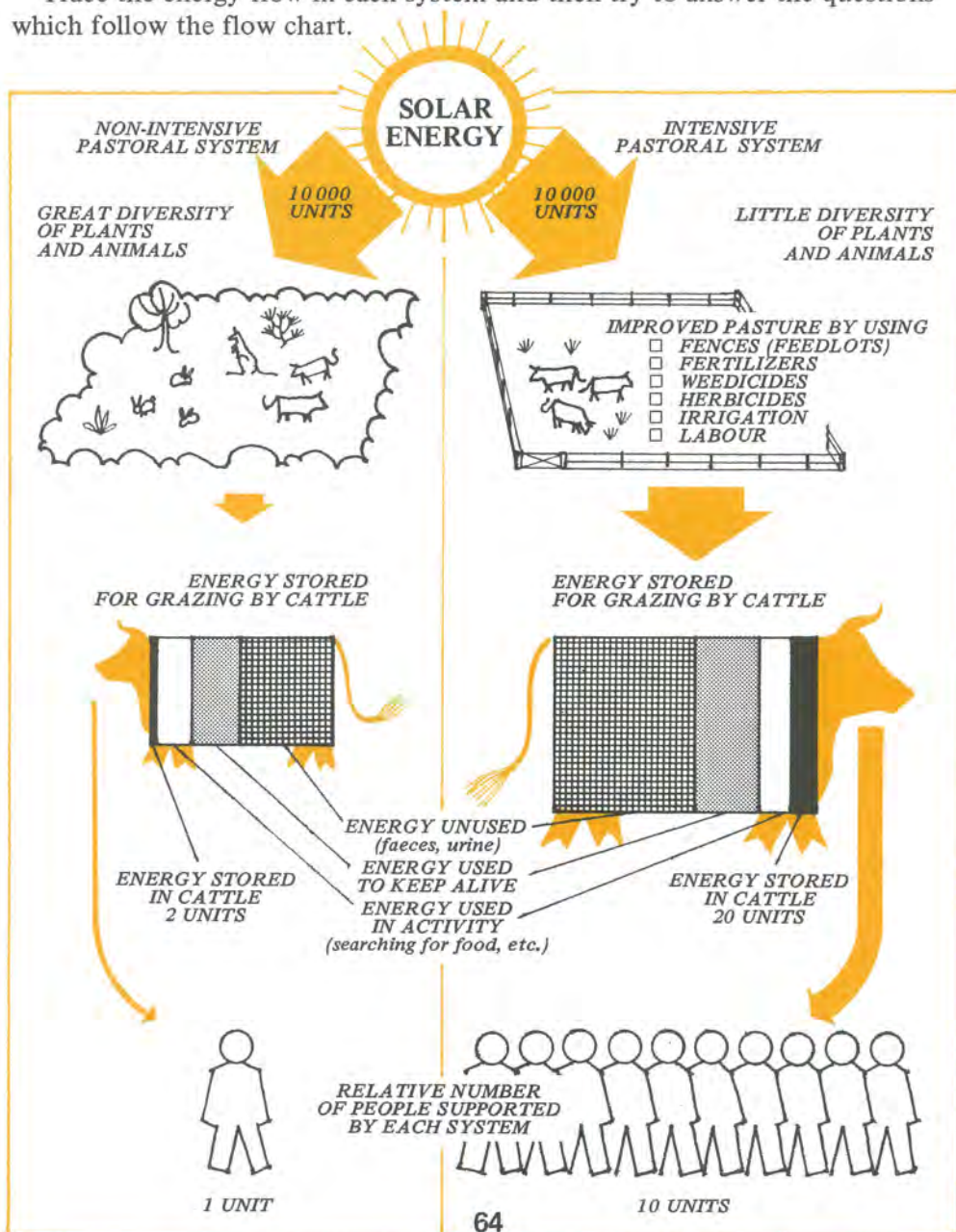
Do we or do we not make the best use of solar energy which can be trapped in this way? The flow chart (page 64) may help you to answer this question.

Professor C.N. Watson-Munro of Sydney was chairman of a special committee set up to investigate solar energy research. *The Age*, Melbourne, of 17 November 1973, in its report of the committee's findings, concluded: 'Under the heading of transport, the committee says trees and plants represent an enormous store of solar energy which can be converted to fuels, such as hydrogen, methane and alcohol. Research is necessary into economic methods of conversion of plant material, and the breeding, selection and growing of plants. One waste material, wheat straw, amounts to 15 million tonnes annually which is equivalent to 10 per cent of Australia's total energy needs. Converting factories could be established in areas where material is available if research is successful.'

SOLAR ENERGY FLOW CHART

This flow chart compares the flow of energy from the Sun through a non-intensive (open-range) pastoral system with the flow through a more modern (intensive) pastoral system. In both systems it is assumed that plants are eaten by animals, for example cattle, which in turn are eaten by people.

Trace the energy flow in each system and then try to answer the questions which follow the flow chart.





3.4 What inputs can be added to bring about more intensive production?



3.5 Why is the proportion of energy used for animal activity different in the two systems?



3.6 For every two units of energy stored in cattle only one unit is available to people. Suggest possible reasons for this.



3.7 Suggest reasons why people in countries which are short of food tend to eat more grain, for example rice, and less meat than people in food-rich countries.

Many demographers (people who study population trends) believe that population growth will lead to further intensification of food production.



3.8 Try to find examples of present-day intensification. Then discuss some of the advantages and disadvantages of using more intensive methods.

3

It has been estimated that the average consumption levels per day are:

		ASIAN FARMER	AUSTRALIAN FARMER
FOOD {	PLANT PROTEIN	48 g	45 g
	ANIMAL PROTEIN	8 g	45 g
	FAT	28 g	90 g
AMOUNT OF ENERGY THIS FOOD SUPPLIES		8.3 MJ	12.8 MJ
LIFE EXPECTANCY		37 years	71 years

Medical research shows that energy requirements differ for men and women, for different ages, and for different occupations. On an average an adult requires 12 megajoules* of energy per day. Many people in the world lack energy-giving foods.

The areas with rapidly increasing populations lack food most. This unfortunate distribution of world food supplies means that some people are dying of over-eating while others are dying of starvation.

* 1 megajoule (MJ) = 1 000 000 joules. This is roughly the energy used by a 1-bar electric radiator in 15 minutes.

TRAPPING MORE SOLAR ENERGY

Do you believe that there is a need to trap more solar energy? You may like to discuss this question with other students. You could consider the possibilities below in your discussion.

- ☐ **Use more land to grow food.** In discussing this suggestion you should consider what proportion of land you think should be set aside for urban development, recreation, grazing, crops, planted forest, native forest and wilderness.
- ☐ **Select and/or breed plants which convert a higher proportion of solar energy into starch.**
- ☐ **Select plants which grow more rapidly and grow more crops per year.**

You may have other suggestions of your own you would like to discuss.



FOOD PRODUCTION

The table below and the information which follows it may help you decide what type of food production is the most efficient.

	PERCENTAGE EFFICIENCY*
1 Sugar-beet, in a field, during middle of its growing season	up to 9%
2 Algae	about 4%
3 Productive woodlands	about 3%
4 Agricultural yields over a whole growing season	about 1%
5 All land vegetation, including crops (average for the Earth)	about 0.3%
6 Total food produced on the inhabitable part of the Earth's surface	about 0.001%

$$* \text{ percentage efficiency} = \frac{\text{energy stored}}{\text{energy received}} \times 100$$



A scientist checking the results of experiments to improve the yield of crops.

Careful estimates have been made of the possible maximum net crop production for the various regions of the world. These estimates have taken into account temperature, amount of sunshine and rainfall.

The length of the normal growing season for many crops is four months. During the summer, temperate regions receive many hours of sunlight, which could enable them to produce up to 380 kilograms per hectare per day. These regions are thus best suited to crops with a short growing season—wheat, for example.

Although a warm tropical climate appears to encourage growth, the estimated maximum crop production for the tropics is lower, as little as 270 kilograms per hectare per day. The lower productivity is due to the effect of fewer hours of sunlight, high temperatures and the differences in soil nutrients.

QUESTIONS FOR THE FUTURE

You may be interested in discussing one of the topics below with other students. These are the kinds of questions which will have to be answered by mankind in the future.

While you are considering them, you could take these figures into account:

	Grazing Area	Cultivation Area	World Population
PRESENT	2000 million hectares	1400 million hectares	3500 million
FUTURE	5300 million hectares available	3200 million hectares available	?



3.9 There is space on page 29 of your record book for any reports that you may want to make.

- ☐ Should all of the Earth's surface suitable for agriculture be used for food production? This would involve clearing large forest areas. Land at present considered waste land, away from populated areas, could be used to produce crops.
- ☐ Is the sea a source of food which mankind should develop more? There are about 10 hectares of ocean for every hectare of land available for agriculture. How could the ocean areas be used?
- ☐ Should we consider only how many people could be fed, when talking about the population of the future?

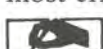
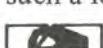


ACTIVITY 5: THE ENERGY GAME

Now play the game that goes with this option.

The game represents energy use in 'real' life to a certain extent.

After you have played the game, try to answer the questions which follow here.

-  3.10 What connection does the game suggest between usable energy and money?
-  3.11 What factors might lead to changes in the cost of energy?
-  3.12 In what situation in the game would it pay to 'hold' energy units?
-  3.13 Which properties would be most affected by changes in the cost of energy units?
-  3.14 Why do the rules specify that solar energy can be converted, but not stored?
-  3.15 Which properties use solar energy most efficiently?
-  3.16 Why has the grazing property such a low solar conversion rate?
-  3.17 If you wanted to modify the game to make it more realistic, what would you want to change?

My game's oil-
what's yours?



OPTION



Although the Sun is about 150 million kilometres away from Earth, much is known about it. In this option you study sunlight and see how some of the information about the Sun has been obtained.

Finding Out About the Sun



A sun-dial.

Each of the instruments shown in these photos is able to tell people, in an indirect way, something about the Sun. From the radiations the instruments receive, a total picture about the nature of the Sun emerges.

In *The Visible and The Invisible*, pages 12–16, you found that sunlight was made up of a spectrum of colours. In the activities which follow here, you can examine various spectra* to see what a spectrum can tell you.

* 'Spectra' is the plural of 'spectrum'.



Special Sun telescope, at Culgoora, NSW. When in use the telescope is open to the air. (Photo by courtesy of CSIRO Division of Physics.)



A radio telescope—Parkes, NSW. (Photo by courtesy of CSIRO.)

ACTIVITY 1: MESSAGES FROM WHITE LIGHT



Warning: You should not look directly at the Sun either through any instrument or with the naked eye, in any of the work which follows—or at any other time. You can cause serious damage to your sight by looking directly at the Sun.



You will need:

- 1 spectroscope
- 1 lamp containing a standard 100 W globe
- 1 lamp containing a fluorescent tube—optional.

As you found out in *What Is Solar Energy?* a spectroscope is an instrument which allows you to analyse light.

If you have forgotten how to use a spectroscope, turn back to page 12.



4.1 Look very carefully at a spectrum obtained by pointing the spectroscope to a part of the sky away from the Sun. Try to pick out features that perhaps you didn't notice before.



4.2 Now point the spectroscope toward a glowing 100-watt globe. This globe contains a very fine wire (filament) heated very strongly. Does the light from the globe produce a spectrum similar to sunlight? Is there more or less of any particular colour in the spectrum? In what ways, if any, does the spectrum of the globe differ from the spectrum of sunlight?



4.3 If you have a fluorescent light, analyse its light with the spectroscope. Describe the fluorescent light spectrum. Include a sketch to show its appearance.

Quickly compare the spectra by looking at them again. You may be able to add observations to those you have already made in 4.1 and 4.2.

4

Prism spectroscope used in the examination of spectra.



ACTIVITY 2: MESSAGES FROM COLOURED LIGHT

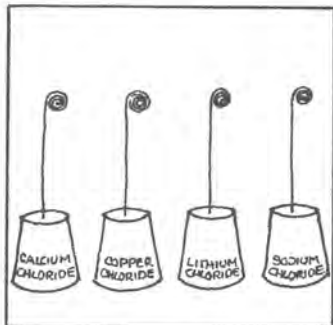
Many substances can give similar colours to gas flames. In this activity you will find out how a spectroscope can help you to distinguish between the substances.

You will need to work with another student. One can colour the flame while the other looks through the spectroscope. You can take turns.

Work in a position in the room where you are away from direct sunlight. Ideally, you should work in a darkened room.

You will need:

- 1 spectroscope
- 1 g calcium chloride
- 1 g copper (II) chloride
- 1 g lithium chloride
- 1 g sodium chloride
- 4 lengths nichrome wire, each about 10 cm
- 4 corks
- 1 gas burner
- 1 stand with clamp to hold the spectroscope.



Wind one end of each piece of nichrome wire into a tight spiral. Insert the other ends into the corks. Label each cork with the name of one of the chemicals in the list.

(These wires may have been prepared for you.)

For the first round of tests, use each wire only with the chemical named on the cork.

Adjust the gas flame so that it is as colourless as possible. You will need to have the air-hole wide open.



4.4 Examine the gas flame with the spectroscope and describe its spectrum.

During this activity, you will be holding the wires one by one in the gas flame to check spectra of chemicals.

You will need to ensure that each wire is clean each time before you begin. If there happened to be other chemicals on a wire the results of a test could mislead you.

To ensure cleanliness, strongly heat the spiralled end of each wire in the gas flame each time. If the flame remains colourless, you can assume that there is no chemical on the wire.

If a wire isn't clean, keep heating it until no colour appears in the flame.



Now select one of the chemicals and its corresponding wire.

Heat the spiral until it glows red. Then quickly dip it into the chemical to make some crystals stick to the wire.

Hold the spiral in the edge of the gas flame. You should get a coloured flame. One partner can hold the wire and the other can look through the spectroscope—and tell what he sees.

You will find viewing easier if you support the spectroscope on a stand.



4.5 Record your observations on the table on page 33 of your record book.



4.6 Repeat the investigation for each of the other chemicals and their corresponding (clean) wires.

Calcium chloride and lithium chloride produce flames of similar colours. Can you tell them apart by looking at their spectra?

The spectrum each chemical produces is called a **line emission spectrum**. It consists of a number of coloured lines. Each **element** has its own particular **line spectrum** which identifies it just as your finger-print can identify you. You may be able to use a different calcium compound and compare its spectrum with that of calcium chloride.

Also, you may like to mix a small amount of any two of the chemicals you tested, and look at the combined spectrum.

By using the spectroscope and comparing the spectrum with your results in 4.5 and 4.6, you may be able to tell which chemicals were mixed.

4

MESSAGES FROM GAS SPECTRA



In the centre pages of this book are several photos of spectra. You will see the spectra of two colourless gases, hydrogen and helium. Their spectra have been obtained from the glow produced when the gases conduct electricity in special tubes.



4.7 Some types of street lights and advertising signs contain gases or vapours at low pressure. It may be possible for you to examine their spectra at night by using a spectroscope. What are some of the substances used in such lights?

MESSAGES FROM THE SUN'S SPECTRUM

Examination of the Sun's spectrum with a good quality spectroscope shows that it is crossed by a large number of fine dark lines. A German physicist, Josef von Fraunhofer (1787–1826), studied the lines in about 1814. They are now named after him.

He explained that for a dark line to appear, some light of a particular energy must be absorbed. Since some dark Fraunhofer lines are in the same positions in the spectrum as some of the bright lines of elements known on Earth, this provides a clue about the elements in the Sun.

Spectral lines of elements on Earth can be matched with lines in the solar spectrum. It is not an easy task, but 60 elements have been matched in this way.

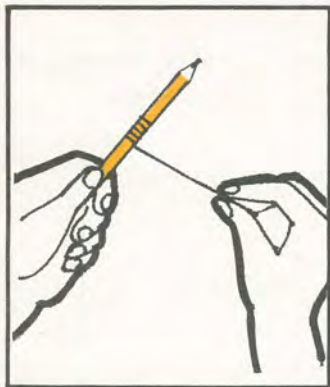
These 60 elements, and probably traces of others, are now believed to exist in the Sun.

The element helium* was actually discovered in a solar spectrum before being discovered on Earth in 1895. The Sun is mainly hydrogen and helium (96 to 99 per cent). The other elements make up the balance.

The solar spectrum can also indicate the temperature of the surface of the Sun. You can test this in the next activity.

* From *helios*,
the Greek word for Sun.

ACTIVITY 3: TEMPERATURE MESSAGES IN THE SOLAR SPECTRUM



You will need:

- 1 length of clean nichrome wire, about 15 cm
- 1 lamp with 100 W globe
- 1 spectroscope
- 1 gas burner
- 1 cork.



4.8 Wind the wire around a pencil to produce a tight coil, but leave enough to insert into the cork.

Heat the coil to red heat in the gas flame.

Describe the spectrum of the red hot coil.

Point the spectroscope at the switched-on 100-watt globe, which contains a white hot wire. Describe the spectrum of the white hot wire. What happens to the proportion of blue light in the spectrum at higher temperatures?

From evidence such as this it is estimated that the surface of the Sun has a temperature of about 6000°C . It has been calculated that its interior temperature may be as high as 20 million degrees.

This method has also been used to estimate the temperatures of distant stars. Some are believed to be much hotter than the Sun.

How can these mighty stellar furnaces keep going? The energy released is believed to come from nuclear reactions. One explanation given is that at those high temperatures, hydrogen nuclei fuse to form heavier helium nuclei. In this process, known as **fusion** (see Option 1), much energy is released.

The Sun is believed to convert mass into energy at a rate of about 4500 million kilograms per second. Even at this rate there would be enough hydrogen fuel to last thousands of millions of years.

SKYLARK AIDS IN RESEARCH ON SUN

CANBERRA. — A British Skylark research rocket was launched successfully at Woomera on Monday in a joint experiment between London's University College and the Nasa Skylab Space Station.

The experiment is aimed at increasing knowledge of the Sun.

The exact moment of the launching was co-ordinated with Skylab's minute-by-minute movements.

After the rocket cleared the Earth's atmosphere, equipment on board took X-ray pictures of the Sun. Information on the wavelengths of the X-ray spectrum was radioed back to Earth.

The Skylab astronauts simultaneously made observations of the Sun with solar telescopes.

The information from the two sources will be combined and compared by computer.

Scientists are hoping for new knowledge about the temperature of the solar corona, the hot gases around the Sun.

More may be found out also about the Sun's process of creating high-energy X-rays.

The experiment paid particular attention to the regions surrounding Sun spots, the birth place of solar flares.

The Skylark research equipment was developed by Dr. John Parkinson, of the Mullard Space Science Laboratory, at London's University College, and was proved in earlier Skylark rockets at Woomera and Andoya, in Norway.

The Department of Supply's weapons research establishment, which operates the Woomera rocket range, assisted the launch, provided and operated tracking instruments and helped with payload recovery.

MORE ABOUT THE SUN

The following are suggestions for further investigations. You could team up with others and obtain extra information on various topics concerning the Sun.



4.9 Record your findings on pages 34 and 35 of your record book.

THE OUTER LAYERS OF THE SUN

You could find out about:

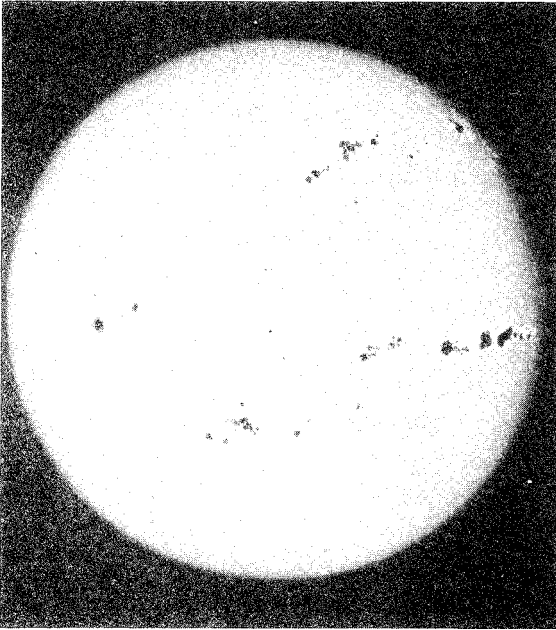
- ☐ the **photosphere**—the part of the Sun we can see, and/or
- ☐ the **chromosphere** and the **corona**—the parts of the Sun we can't see unless there is a total eclipse of the Sun.



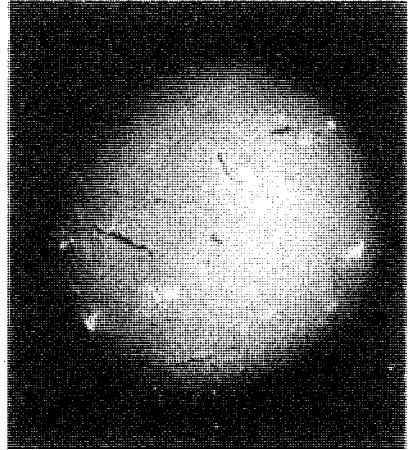
An eclipse of the Sun.

(Reprinted, with permission, from The Age, Melbourne, 28 November, 1973.)

SPOTS ON THE SUN



The photo at left shows the Sun, taken with film sensitive to white light.



About 450 B.C. the ancient Greeks recorded the presence of dark spots on the Sun. So did the Chinese about 165 B.C. These are now called sunspots. They could have been observed by the Greeks and Chinese when the Sun was partly hidden by smoke or haze. Sunspots have been closely studied ever since, but there is still no generally accepted explanation of their cause.

Sunspots often appear in groups. Their numbers build up to a maximum about every 11 years and then decline.

Find out more about sunspots. For example, do they always look the same? Do they stay in the same place?



The two photos above show the solar chromosphere photographed on a special film. The dark markings are filaments which at the limb (the rim) are seen as prominences.

(Photos on this page by courtesy of the CSIRO Division of Physics.)

SOLAR PROMINENCES

For centuries, during eclipses, people have observed red, flame-like structures—**prominences**—rising above the rim of the blacked-out disc of the Sun.

Solar prominences appear to be material thrown out from the Sun, usually near regions of sunspot activity. Motion pictures show some material moving from the prominences back to the Sun.

What else can you find out about solar prominences?



Aurora.

(Photograph by D.Pares, by courtesy of ANARE.)

SOLAR FLARES

Occasionally, in a small region of the Sun near sunspot groups, an enormous amount of energy is released. The visible radiation emitted is small compared with that from the entire Sun. However, the ultra-violet radiation may actually 'outshine' the Sun. Also, X-rays and nuclei of atoms are thrown out at high speeds. This type of activity is called a solar flare. No one yet knows what causes solar flares.

The Sun gives out high bursts of radiation, particularly when sunspots are at a maximum. These bursts affect the Earth.

AURORAS

Observers in the mid-nineteenth century noted that sunspot activity is linked to magnetic storms on Earth.

During these storms there are brilliant auroral displays—coloured patterns high in the sky. These patterns are created by particles from the Sun which enter the Earth's magnetic field. Most particles spiral down toward the Earth's magnetic poles, causing the atmosphere to glow.

At these times, radio communications between parts of the world distant from one another are either totally or partly lost. By studying the Sun, periods when these effects will occur can now be predicted. You could find out more about solar flares and auroras.

COSMIC RAYS

Astronauts in space are exposed to a very penetrating type of radiation—cosmic rays. Some solar flares produce bursts of cosmic rays.

What are cosmic rays? Where else do they come from? What problems could they cause astronauts? Why do we not suffer harmful effects from them here on Earth?

RESEARCH ON THE SUN

The Sun is pouring energy into space in a number of ways. By studying the energy it is emitting, mankind has gained a considerable understanding of the Sun.

Here in Australia, for example, at Culgoora, New South Wales, the CSIRO operates a refractor telescope for optical study of the Sun.

You could find out about the work done at Culgoora.

What use, for example, is photographing the Sun through selected filters?

Despite all the research, there still remain features that have no explanation—for example, the causes of sunspots and flares. In the future, perhaps space laboratories above the Earth's atmosphere may find the answers.



*Large sunspot group near the Solar limb, photographed in white light.
(Photo by courtesy of CSIRO Division of Physics.)*

OPTION



You know the Sun is radiating energy to the Earth. In this option you make an estimate of how much it radiates in one second. (An option for those interested in measurement and maths.)

Watts Up There?

To find the rate at which things are happening, two measurements have to be taken:

- ☐ the amount of change, and
- ☐ the time taken for the change.

For example, moving 20 metres in 2 seconds is a rate of 10 metres per second ($\frac{20}{2} = 10 \text{ m/s}$).

Water flow can be measured in litres per second. A car's petrol consumption is measured in litres per 100 kilometres. But what about energy flow?

Energy is measured in joules. A joule is a small quantity of energy. If a cup of water (about 200 millilitres) absorbed 1 joule of energy, the usual laboratory thermometer would show no temperature change. Even if 1000 joules (1 kilojoule) were absorbed, the temperature would rise only from, say, 20.0°C to 21.2°C.

One million joules (1 megajoule) would be enough to boil two cups of water and turn the water completely into steam.

If a source supplies 1 joule of energy in 1 second, this rate is called 1 watt. (1 joule per second = 1 watt)

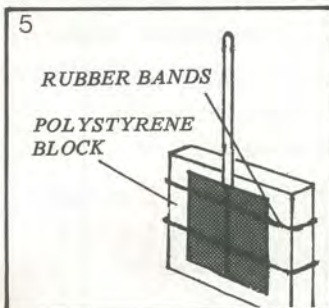
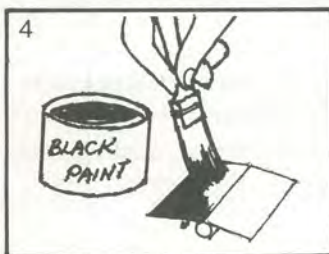
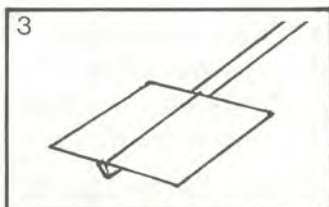
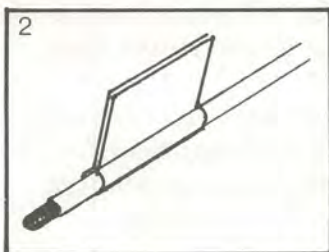
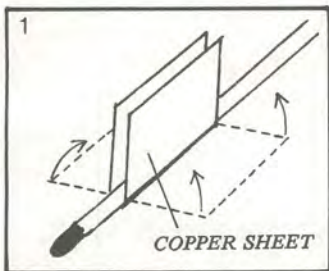
In this option you measure the **rate in joules per second (watts)** at which the Sun radiates energy—that is, you measure the **power output** of the Sun.

To do this you need to construct an energy-absorber.

Notes on the Construction and Use of an Energy-absorber

- 1 You will construct an instrument which will absorb radiation falling on its surface—an energy-absorber.
- 2 You will use light globes, on which the power output is indicated, to relate the reading of the instrument:
 - ☐ to the power of the globe, and
 - ☐ to the distance between the globe and the instrument.
- 3 Once you have found this relationship you will have an instrument which is said to be **calibrated**. You can then use it to estimate the power output of the Sun.

ACTIVITY 1: CONSTRUCTING AN ENERGY-ABSORBER



You will need:

- 1 thermometer, -10°C to 110°C
- 1 sheet of thin copper foil, about $6\text{ cm} \times 6\text{ cm}$
- 1 tin of flat black paint
- 1 block of polystyrene plastic foam, about $9\text{ cm} \times 9\text{ cm} \times 2\text{ cm}$
- 2 rubber bands
- 1 small paint brush
- 1 razor blade (or sharp knife).

You have seen that a blackened thermometer bulb is an energy-absorber. It indicates that it has absorbed energy by showing an increase in temperature on the thermometer scale. Increasing the area of the absorbing surface will improve the detecting power of the thermometer. Here's how to do it.

1 Place the thermometer across the centre of the foil.

2 Fold the foil around the thermometer, pressing it tightly around the thermometer stem.

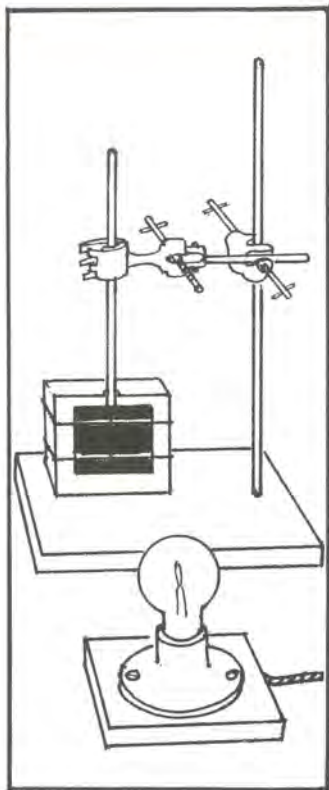
3 Fold the two flat sections out again. The thermometer must still fit tightly in the foil tube. Squeeze the end of the tube to stop the thermometer slipping through.

4 Remove the thermometer. Paint the foil on one side only with the flat black paint. Wash the brush thoroughly when finished. Replace the thermometer when the paint is dry.

5 To insulate the instrument so that it does not reradiate heat too quickly, use the plastic block. Mark an outline of the thermometer and the absorbing surface on the plastic block. Use the razor blade to cut a depression into which the instrument will fit neatly. The rubber bands may be needed to hold it in position.

The energy-absorber is now ready for use.

ACTIVITY 2: USING THE ENERGY-ABSORBER



You will need:

- the energy-absorber
- 1 extra thermometer, -10°C to 110°C
- 1 stand
- 1 metre ruler
- 1 clear globe, 100 W
- 1 clear globe, 25 W

Set up the equipment as in the diagram at left, out of direct sunlight.

Place the energy-absorber on the same level as the 100-watt globe, exactly 20 centimetres from the centre of the globe.

Place the second thermometer about one metre away. With this you will be measuring the air temperature. This second thermometer must not be affected by the globe or sunlight during your measurements.



5.1 On page 36 of your record book, record the reading on the thermometer in the energy-absorber. In this and all following readings record the temperature to the nearest 0.5°C .

Now turn on the globe. Observe the readings on the energy-absorber until the temperature stops rising (about 10 minutes).



5.2 Record the maximum temperature on the energy-absorber. Also record the air temperature at the time the maximum reading was made. What is the difference between these two readings?

You have now made an instrument which records absorbed energy as a temperature increase.



5.3 When the temperature stopped rising, had the instrument stopped receiving energy? Give reasons for your answer.

Predict what temperature increase you would expect if a 25-watt globe were used instead of a 100-watt globe. Now test your prediction.

Replace the 100-watt with the 25-watt globe. Place it exactly 20 centimetres from the absorber. Allow the absorber to cool to about air temperature before you start. Then take the same measurements as you did previously.



5.4 Record the readings for the 25-watt globe.



5.5 • Compare the temperature increases for the two globes. What connection, if any, exists between energy and temperature rise?

In this activity you looked at the effect of varying wattage (power) while keeping distance the same (constant). In the next activity you will keep the wattage constant, but vary the distance.

ACTIVITY 3: ENERGY AND DISTANCE

You will need the same equipment as for Activity 2, except for the 25-watt globe.

Set up the equipment as in Activity 2 (page 82), but with 40 centimetres between the 100-watt globe and the energy-absorber.

Make sure you have taken all the precautions outlined in Activity 2. Switch on the globe and allow the thermometer reading to reach a steady maximum.



5.6 Record the thermometer readings and the difference between the two readings. Move the energy-absorber in turn to the 30-centimetre, 20-centimetre, 15-centimetre and 10-centimetre marks. When the thermometer in the absorber has risen to a steady maximum in each position, note its reading in the table on page 37 of your record book. Note also the room temperature each time, as it may not stay constant. Enter the results in the 'temperature increase' column.



5.7 If you plot the information from 5.6 on a graph grid, you may find it easier to follow. There is a grid already drawn for you on page 37 of the record book. Join the plotted points with a smooth curve, if possible.

It is important at this stage to understand the significance of the information you have gathered.

Activity 2 probably showed you that if you reduce the wattage of the globe by a factor of four (100 watts to 25 watts), you also reduce the temperature increase by about the same factor. The absorber really gives an indication of wattage.



5.8 Try to complete the calculation in your record book.

It probably appeared that increasing distance by a factor of two reduced the temperature increase by a factor greater than two.



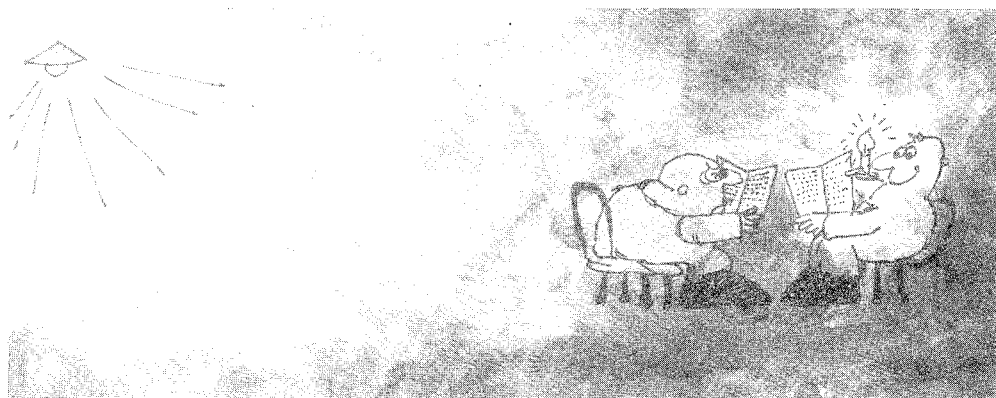
5.9 Try another pair of distances. Complete the calculations of the factors in your record book.

Did you find your final factor was close to four? In other words, doubling the distance reduced the amount of energy received on the energy-absorber by a factor of four.

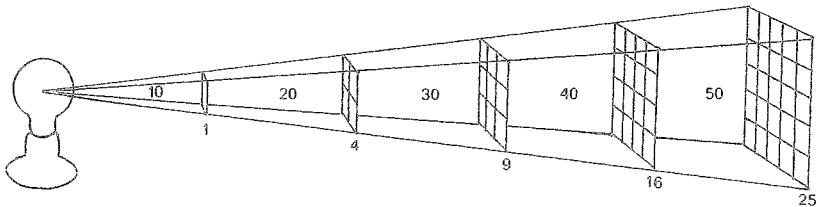


5.10 What happens if you increase the distance by a factor of three or four? Complete the calculation of the factor in your record book for the distances given.

Build up a summary by completing the table of results on page 38 of the record book.



Your results may be different from what you expected. The diagram below may explain.



The energy spreads out from the filament of the globe. One unit of length away from the globe the energy passes through one square. But two units away from the globe, the energy passes through four squares. Therefore the energy that passed through one square must pass through four squares when the distance is increased by a factor of two.

At three times the distance, there are nine squares and the energy through one square is reduced by a factor of nine.

At four times the distance, the factor is 16.

What is the factor when distance increases five times?

By now you can probably see the pattern.

If you increase distance by a factor of two, the energy absorbed decreases by a factor of 2×2 .

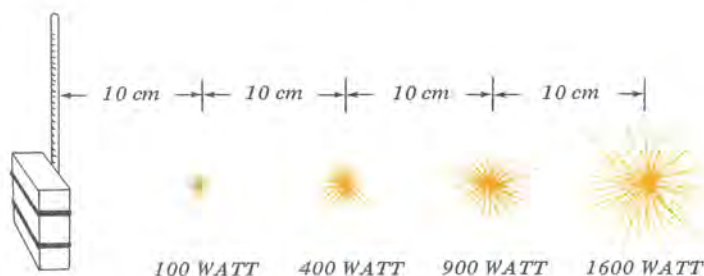
Similarly:

DISTANCE INCREASE FACTOR (cm)	2	3	4	5	n
ENERGY DECREASE FACTOR (watts)	2×2	3×3	4×4	5×5	$n \times n$
That is:	2^2	3^2	4^2	5^2	n^2

How well did your measurements with the energy-absorber fit the pattern? This will depend partly on how accurately you measured the various temperatures.

If there is not an approximate agreement, check the calculations you made in 5.8, 5.9 and 5.10. You may wish to repeat certain measurements in 5.6.

There is another way of looking at this pattern. Look at the diagram below.



A 100-watt source 10 centimetres from the energy-absorber raises its temperature by a certain amount. A 400-watt source 20 centimetres away would give the same increase, so would a 900-watt source 30 centimetres away, and so on.

The wattage and distances in the diagram above should give identical increases in the energy-absorber.

If you like, you could check on this idea by using your 100-watt and 25-watt globes. Where would you expect the 100-watt globe to be placed to give the same temperature increase as a 25-watt globe 10 centimetres from the energy-absorber?

ACTIVITY 4: POWER FROM THE SUN

Now you should be able to measure the power output of the Sun.

The Sun is very many centimetres away from the Earth. Actually, it is about 15 million million centimetres away. (Fifteen million million is sometimes written 15×10^{12} . The 10^{12} tells that 15 has been multiplied by 10 twelve times.)

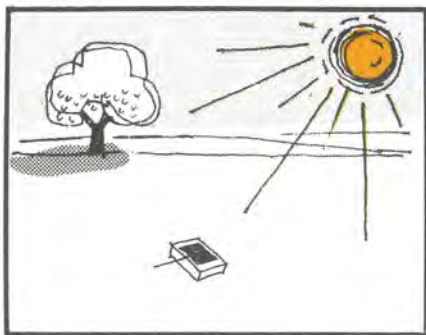
If you can find the temperature increase of the energy-absorber exposed to the Sun, and then find where a 100-watt globe needs to be placed for the same increase, you can estimate the Sun's wattage (power).

You will need:

- the energy-absorber
- 1 extra thermometer, -10°C to 110°C .

If possible, choose a sunny, windless day to make your measurements.

Place the energy-absorber on the ground, away from buildings, so that it points directly at the Sun.



When the temperature reaches a steady maximum—after about 10 minutes—read the energy-absorber and also the shade temperature.

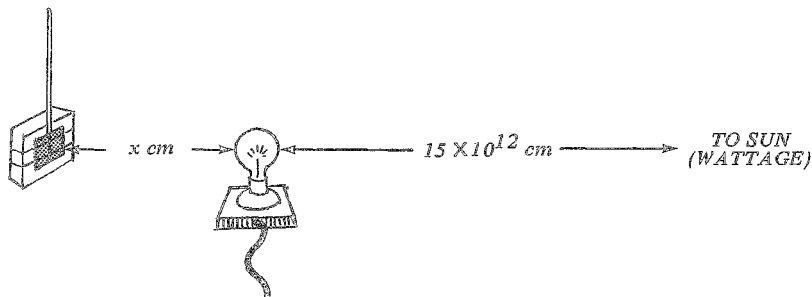


5.11 Record both temperature readings in your record book and calculate the increase.

5



5.12 Look at the graph in 5.7, and at your calculation in 5.11. How far from a 100-watt globe did you get the same temperature increase as that produced by the Sun? Enter your answer in your record book to the nearest centimetre.



To move from the 100-watt globe position to the Sun means increasing the distance by a factor which you can calculate. Suppose it is one million (it isn't!). Since the energy-absorber gives the same reading, the wattage obviously has to increase, too. From your previous work you know that the wattage would increase by a factor of $1\,000\,000 \times 1\,000\,000$.



5.13 Complete the calculation of the wattage of the Sun in your record book.



5.14 A value is quoted in the record book for the wattage of the Sun. It is an estimate of the actual rate at which energy is leaving the Sun. Your answer may differ greatly from that in the record book. Suggest possible reasons.

Check Your Answers

Check your answers with the answers given here. If you cannot agree with a given answer, discuss it with another student, or go back to the particular section of work and read that section again.

If you are still in doubt, ask a teacher.

WHAT IS SOLAR ENERGY?

- 1 Water in the dam has potential (stored) energy. Solar energy evaporates water from the sea. This water falls as rain which finds its way into the dam. As this water returns to the sea its energy is transformed to other forms—for example, electricity.
Coal is formed from plants, which depended on solar energy for their growth. This energy is stored in coal (as chemical energy).
- 2 The energy for a 'dry' cell comes from reaction between chemicals inside the cell. A nuclear power station obtains its energy from the splitting of uranium atoms (fission).
Underground steam is produced by heat from within the Earth.
- 3 Radio waves carry energy to the receiver. Chemical energy stored in chemicals in the cells is transferred to electrical energy for use in the receiver. Kinetic energy in the vibrating speaker causes the air to vibrate. Our ears pick up these vibrations and our brains interpret them as sound.
- 4 You probably found that the vanes of the radiometer rotated in the light, but not in the dark. (Did you notice which way the vanes moved? Did the shiny side or black side lead?) They would have also rotated near the heat source.
- 5 Any theory should fit the observed behaviour of the radiometer. Further observation may make you change the theory.
- 8 The black coating is a good heat absorber. The readings on the black-coated thermometer probably showed a much quicker increase than the readings for the uncoated one. The final reading for the coated thermometer was also probably higher. You may have decided now that heat rather than light was responsible for the movement of the vanes.
- 9 You probably saw a band of colours from red to violet at the side of the tube.
- 10 Coloured filters transmit light of their own colour and absorb the rest of the visible spectrum. For example, a pure red filter would transmit red and absorb the other colours. The white light spectrum would appear black everywhere except in the red section. Coloured filters that are combinations of two or more colours will transmit these colours.
- 11 Shiny white paper reflects most incoming light. The spectrum of light reflected from shiny paper is probably a white light spectrum.
Dull black paper absorbs light of all colours and reflects none. Hence it appears black. There would be no reflected light spectrum.
(What might happen if the black paper had a shiny surface? You could test your suggestions.)

What Is Solar Energy? continued next page

What Is Solar Energy? (continued)

- 12 The spectroscope shows the colours of light reflected from the various surfaces. For example, a green leaf probably reflected green and some orange light.
- 13 A yellow filter transmits yellow. It absorbs any other colour.
A red surface reflects red. It absorbs any other colour.
It may be useful to keep in mind the difference between transparent and opaque materials. If a transparent material is held up to the light, it appears to have a certain colour because it transmits certain radiations and absorbs the rest. The colour is due to the white light having certain colours removed (absorbed) by the transparent material. For example, a yellow solution such as potassium chromate absorbs blue light and transmits a combination which appears as yellow.
- 14 From A you probably noticed a reddish tinge in the transmitted light. From B, the light probably seemed bluish. The colours were probably very faint.
- 15 Red sky As you look toward the horizon at sunset, any sunlight which is reaching you has had to travel a long way through the Earth's atmosphere. By the time it reaches you most of the high energy blue light pulses have been scattered. The red section of the spectrum reaches your eyes.
Fog lights Small water droplets in a fog scatter most of the white light so that it can't penetrate the fog. (The fog looks like a white wall.) The red-orange-yellow parts are scattered less so that a light of this colour will penetrate farther. A fog light can light up some of the road.
- 16 Results which have been obtained by a comparison with white paper (taking the reading for white paper as 100 per cent):

SURFACE	PERCENTAGE OF LIGHT REFLECTED
WATER: RAYS VERTICAL	2
WATER: RAYS GRAZING SURFACE AT A LOW ANGLE	very high
SNOW OR ICE	46-86
GRASS	14-37
FORESTS	3-10
BARE GROUND	7-20
CLOUDS	40-80

- 19 The spectrum probably seemed to be green and red with most of the blue-violet of a white light spectrum missing.
(Is the result due to the colouring material or the alcohol, or both? How could you find out? Try it.)
- 20 The temperature readings probably increased over the period. The readings for the thermometer inside the glass covering were probably higher than those for the thermometer outside.

TEST YOURSELF—WHAT IS SOLAR ENERGY?

1 B

A, C These are kinds of energy which were originally derived from the Sun but would not normally be described as solar energy in their present form.

D Solar energy consists of a large spectrum of radiation. Light energy is only part of this spectrum—the visible part.

2 A

B, C, D, E

A very small part of the electrical energy may be changed into one or more of these forms. For example, if the plate is heated very strongly it may glow.

3 C

4 A

5 B

6 A

7 F

8 A

9 E

10 B The colour of an object (like grass) which you see is the part of the light which is reflected from the object to your eyes.

11 A black object absorbs more infra-red radiation than a white object. When infra-red radiation is absorbed by an object, the object gets warmer.

12 Hydro-electricity is obtained indirectly from solar energy. Turbines, which are driven by falling water, turn the generators which produce electricity. It is solar energy which evaporates the water from oceans, lakes, etc. in the first place.

13 A When the radiometer is placed in direct sunlight, the vanes begin to spin. The radiant energy of the Sun (mainly infra-red radiation) is converted into kinetic energy (energy of motion).

Test Yourself continued next page

- 14 C
- A All forms of radiation which make up the solar spectrum travel at the same speed—approximately 3×10^8 metres per second.
 - B Most forms of radiation from the Sun cannot be seen and therefore have no colour.
 - D The various kinds of solar radiation do not travel along separate and distinct paths from the Sun to the Earth.
- 15 D
- A Visible light is a lower energy radiation than ultra-violet radiation. Energy changes don't occur in this direction (low to high energy) unless some outside energy is added.
 - B Read through Activity 7 (The Glasshouse Effect), on page 26 of *Solar Energy*.
 - C Glass transmits high energy radiation, but reflects low energy radiation.
- 16 B
- When white light from the Sun passes through the atmosphere, scattering of the light by small particles such as dust and water vapour occurs. The higher the energy, the greater is the scattering. The radiations at the blue-violet end of the spectrum are thus scattered more than the radiations at the red end.
- 17 B
- If white light falls on a transparent red substance, like the red dye, then normally the colours at the red end of the spectrum would be transmitted while the other colours would be absorbed. The spectroscope would therefore show only colours at the red end of the spectrum.
- 18 D
- The bluish piece of cardboard reflects colours at the blue end of the spectrum. Other colours are absorbed. The spectroscope would therefore probably show a blue-violet colour.
- 19 A
- The farther away an object is, the more likely it is that radiation from it will be scattered. This scattering reduces clarity. Ultra-violet radiation is scattered most, and infra-red scattered least.
- 20 C
- Because infra-red radiation has a lower energy than that of green light it is absorbed by the gas. Ultra-violet radiation is transmitted and can be detected by the film.
- 21 C
- Infra-red and ultra-violet radiation cannot be seen. The orange-yellow radiation would be absorbed by the gas.

OPTION 1: THE EARTH'S ENERGY RESOURCES

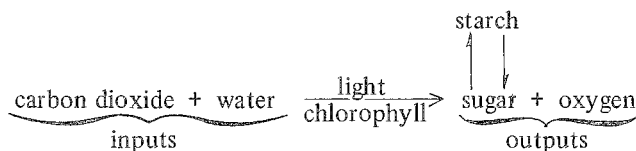
- 1.1 Running water and wind limit where you can build energy convertors. You cannot rely on the wind blowing when you require its energy.
- 1.2
 - a) There are marked increases in the amounts of energy being used and likely to be used in the future in both countries.
 - b) The USA has started using nuclear energy. The USA uses much more energy per head than Australia.
 - c) By the year 2000 Australia may be using nuclear energy and may be using less fossil fuel. Direct use of solar energy is also a possibility. (See Option 2.)
- 1.3 An industrial country with a high standard of living uses more energy than a non-industrial country. The USA is more industrialized than Australia which in turn is more industrialized than India. More industry usually means that more materials can be produced. Living standards usually rise as a result.
- 1.4 New Zealand has a high production for a relatively low energy requirement because of its largely agricultural background. The United Kingdom has more industry and a much higher energy requirement. The value of its production does not differ greatly from New Zealand (per head of population).
- 1.5 You probably have many suggestions. The following questions may be useful for further discussion, if you haven't considered them already. How are smogs and fogs formed? Could products of combustion be partly responsible for these? In What Is Solar Energy you saw how the atmosphere controls radiation entering and leaving the Earth. Could the increase in carbon dioxide, for example, affect this control?
- 1.6 The stored energy in the petrol has been transformed to other forms. These include sound, heat and kinetic energy (the energy of a moving object). Friction with the road also transforms kinetic energy to heat. Eventually all the energy of the petrol is transformed to heat. Can you see why?
- 1.7 Did you consider the effect that an increase in water temperature in, say, a river might have on animal and plant life there? If run through pipes, the hot water could possibly heat glasshouses to help raise crops. Under the ground, it could raise soil temperatures to improve crop production. Houses could be heated. You may have other interesting ideas.

OPTION 2: DIRECT USE OF SOLAR ENERGY

- 2.4 The best shape is that of a parabola. If you couldn't focus the Sun's rays, bend your cardboard to fit the coloured parabolic curve on page 54.

OPTION 3: ENERGY FOR LIFE

- 3.3 Activity 2 showed that light energy is required for plants to produce starch. Activity 3 showed that chlorophyll is also necessary. Light and chlorophyll are the factors missing from the statement.
The process is usually written



- 3.4 The many inputs include fertilizer, insecticides and irrigation. You may have thought of others in addition to those shown on the flow chart.
- 3.5 In the non-intensive pastoral system animals have to move about in search of food. In the intensive system animals may be kept in small enclosures and have food brought to them.
- 3.6 Some of the energy input is stored as bone, hide, hair, etc., to maintain the animal. Only about half of the mass of an animal is suitable as a source of food for human beings.
- 3.7 Only some of the grain food eaten by animals is stored as food available to human beings. Thus there is an energy loss. Grain foods eaten directly by people do not incur this loss.
- 3.8 Many modern animal food farms use intensification. The animals are kept in small enclosures, so they can't move about, and are fed a special fattening diet. The 'normal' growth rate is increased quite considerably.
- 3.10 Obviously, energy costs money. To obtain energy, you need money. Also, you can exchange your energy reserves for money (cash in hand). The actual cost of the energy varies, depending upon such things as the type and source of the energy and the general availability of energy in the community.
- 3.11 Whenever demand for energy exceeds the supply, it creates an economic shortage. This increases the cost of energy. Unpredictable shortages of energy occur during any industrial disputes which involve the supply of energy. Natural disasters such as droughts, floods, earthquakes, etc., can also disrupt energy supplies.
- 3.12 It pays during a crisis, when energy supplies are short. In this way the value of energy units is increased.
- 3.13 Properties requiring high energy inputs such as the transport company and the factory were most affected.
- 3.14 Solar energy must be converted to some other form of energy if it is to be stored. (See Option 2.) Thus if the game is to relate to 'real life' this rule is essential.

- 3.15 The most efficient properties are those which produce food and have a high solar energy conversion rate; for example the algal food production centre. The products of these properties are all plants. In plants, solar energy passes through only one conversion step before it is stored. Thus only one energy loss occurs.
- 3.16 The product of the grazing property is cattle (meat). Energy used to fatten cattle comes from the starch in plants. The energy used by plants to produce starch comes from solar energy. Thus two conversion steps are involved. Energy loss occurs twice.

OPTION 4: FINDING OUT ABOUT THE SUN

- 4.1 You probably would have seen a spectrum where one colour runs into the next. This is a **continuous spectrum**. Did you notice any vertical fine black lines? If not, go back and look more closely at a solar spectrum. Using a good quality spectroscope, you can see these lines easily. They can also be seen in the colour reproduction of the Sun's spectrum in the centre of this book.
- 4.2 You probably didn't notice any difference between the solar spectrum and the spectrum of the 100-watt globe. With a good quality spectroscope you would have seen less of the violet end in the spectrum of the 100-watt globe.
- 4.3 The spectrum of a fluorescent light shows the continuous spectrum crossed vertically by a number of bright, coloured lines. These lines are in the blue, green and yellow regions.
- 4.4 In a darkened room you would probably see little colour from the flame. If sunlight enters the room, you may get a weak white light spectrum. This background will probably appear in the spectra you see in the next activities.
- 4.5 Each substance produces a bright line spectrum. You may not be able to see them clearly with your spectroscope. The flame colours are: calcium—red;
- 4.6 and copper—bluish green; lithium—red; sodium—yellow.
- 4.8 The proportion of blue light in the spectrum is greater for a light from a white hot body than a red hot one.

OPTION 5: WATTS UP THERE?

- 5.3 The instrument was then emitting energy at the same rate as it was receiving energy.
- 5.5 You probably found that when you changed from the 100-watt globe to the 25-watt globe the temperature increase was only about one quarter of its previous value.
- 5.12 The distance probably was about 20 centimetres.
- 5.13 Your calculation here should give a final answer of about 3×10^{24} watts.
- 5.14 You may have suggested that the method used is not accurate. You used figures obtained in a room about 20 centimetres from the source. From them you calculated an answer for a distance millions of times greater. Could there be errors here?
The value of 4×10^{26} watts is for energy leaving the Sun. Your method uses figures obtained on Earth to calculate the Sun's power output. But does all the Sun's power output reach the Earth's surface?

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